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9. It will be seen that in para. 17 of the preliminary report the President required the members of the committee to submit notes on questions detailed in that Paragraph. The following notes have been received and are attached to the preliminary report, together with a letter from Mr. Mitchell, the gentleman consulted under the orders of Government:—

Mr. Medlicott	...	...	...	...	Three.
„ Ibbetson	...	...	...	...	Two.
„ Forrest	...	...	...	...	One.
„ Buck	...	...	...	...	One
Captain Howard	...	...	..	...	One

Notes were not received from the Commissioner of Meerut and the Collector of Aligarh, who represented that their inexperience with the subject precluded them from offering any opinion; nor from Mr. Smith, who represented that his duties prevented him from submitting a report before taking leave to England.

10. In para. 18 Government has been informed that a sub-committee was appointed to frame proposals as to the form which experiments or enquiries might take, and their proposals will be found on page xxxvii. of the papers accompanying the preliminary report.

11. I am now desired by the President to submit, in conclusion, his review of the series of papers submitted.

12. The orders of Government are specially required on the proposals of the sub-committee.

I have the honour to be,

SIR,

Your most obedient servant,

E. C. BUCK,

Secretary, Rev Committee.

REVIEW OF THE PROCEEDINGS OF THE REH COMMITTEE
BY H. S. REID, Esq., PRESIDENT OF THE COMMITTEE.

1. TAKING my material from the reports furnished by five members of the *Reh* Committee (Messrs. Medlicott, Buck, Forrest, Ibbetson, and Michel), than whom, each in his own line, no more reliable authorities on the subject of *reh* could be found, I shall attempt in the following paragraphs to show, *firstly*, the conditions under which *reh* is developed in these provinces; and *secondly*, how those conditions are affected by the introduction of canal irrigation. When dissent is not expressed, it may be assumed that I accept the facts and theories of my colleagues as agreeing with the results of my own enquiries and personal observation. I shall travel as little as possible outside their notes, and refer no more than is absolutely necessary to former discussions on the subject.

2. Mr. Medlicott holds that *reh*, which appears on the surface of the ground in the form of a white flocculent efflorescence, is formed of "highly soluble sodium salts, the result of the decomposition by air and water of the particles of rock-minerals to be found in almost every soil, being the waste products of soil formation—the elements unassimilated by vegetation—the gradual removal of which is ordinarily effected by the rain-water draining through the soil and carrying with it any excess of these soluble salts." That it is hardly ever developed in sandy soil both Mr. Forrest and Mr. Ibbetson agree. The former, however, has found it in clayey (*matiyár*) soil, while Mr. Ibbetson states that clay being too close in texture for capillary attraction never shows *reh* other than the scum left by the evaporation of the surface drainage. It may be assumed on Mr. Medlicott's authority that the salts which form *reh* are found in most soils, even where *reh* is not developed. As the gradual removal of these soluble salts is effected by rain-water drainage through the soil, sub-soil drainage water must generally contain *reh*, while mere surface drainage water contains little or none.

3. *Reh*, where it shows as a white efflorescence on the surface, has been brought up from below the soil by the force of capillary attraction, drawing up and evaporating the sub-soil water which holds it in solution. The effect of the evaporating force depends on the distance of the water-table from the surface of the ground and the nature of the intervening soil (Ibbetson). Under the influence of long and continuous evaporating action, fresh accretions of salt are thus brought continually to the surface; and the fact that the most extensive outcrops of *reh* occur chiefly on the scorched plains of Northern India is due probably to the circumstance that evaporation acts more freely in a dry atmosphere, through which radiation can pass unimpeded by vapour (Buck). Mr. Medlicott points out (paras. 11 and 5) that the immediate active cause of the mischief is the *extreme climatal* condition of the area affected, the sun's scorching heat and the desiccated hot winds from which the ground has no protection. Within the continuous area of the Indo-Gangetic plains, it is only in the scorching climate of the North-West that *reh* has become a scourge. It

is quite certain, Mr. Medlicott adds, that evaporation is the immediate cause of the appearance of *reh* as a white crust on the surface, and that its concentration there is the efficient cause of ruined vegetation. Evaporation being thus the immediate developer of *reh*, and water in the soil the necessary vehicle for its operation, the conditions of the water circulation on, in, and under the soil became a main feature of the whole question.

4. It has been proved by facts, Mr. Buck observes (para. 5), that a rise in the level of a main body of water underlying the surface is frequently accompanied by a greater development of *reh* at the surface, and often in new places. These results may possibly be ascribed as well to an increase in the evaporating process due to the approach of the main body of water to the surface, as to a change in the geographical distribution of under-ground accumulations, which with every change in level may find new centres of rest. Mr. Medlicott points out that, though the greatest amount of evaporation takes place at a surface supplied from a shallow water-table, similar results may occur at any elevation wherever the water soaked during the rains is withdrawn again by evaporation. The apparently capricious distribution of *reh* (a great obstruction to a right comprehension of its mode of production) over a uniform surface does not imply a greater amount of *reh* in the ground under that surface originally, but only that more evaporation has taken place there owing to a freer supply of soaking,—this condition being determined by original difference of texture in these old alluvial deposits : a very little more or less of clay quite inappreciable to the eye in different layers, or in different parts of the same bed, would quite account for the very irregular appearances of the efflorescent *reh* and the peculiar aspect of a *ûsar* plain. On the same even surface, level, or sloping, with no visible difference in the soil, *reh* often shows itself most irregularly—bald patches in the midst of cultivation, or cultivated patches surrounded by *reh* ; sometimes the efflorescence is the strongest in the slight depressions, sometimes in the slightly raised area. But, however great the peculiarities above described which shake all preconceived theories, there can be no doubt that when *reh* exists in the soil, it is more largely developed on a surface where the water-level is nearer the surface, and that *reh* will develop in places in which it was formerly unknown if the water-level is raised by whatever cause.

5. Besides the primary conditions at work which have been considered in the preceding paragraphs, there are what Mr. Medlicott styles “secondary influences,” which, though insignificant when compared with the primary conditions, must yet be taken into account. These secondary influences are—

(a)—Local obstruction of surface drainage.

(b)—The possible spread of *reh* by rain-wash and wind-drift.

6. Local obstruction of surface drainage must result in raising the water-level within the area the natural drainage channels of which have been obstructed. The effect of the rise in the water-level in developing *reh* has been explained fully above. On this point there can hardly be two opinions. But Mr. Buck and I differ with Mr. Medlicott and Mr. Ibbetson in our estimate of the influence of rain-wash and wind-drift on

the spread of *reh*. Mr. Ibbetson writes—"I do not believe that *reh* is spread over uncultivated land by wind or surface washing." Mr. Medlicott states that it has been shown experimentally that mere surface drainage is ineffectual for the removal of the salts of which *reh* is formed, although they are accumulated at the very surface as the first drops of rains dissolve, and carry them into the top soil, where they are untouched by the water draining off the surface. Mr. Buck, on the other hand, contends that some part of the early rainfall, which has the opportunity of taking up *reh* in solution, is not absorbed into the soil, but spreads over surrounding land or finds its way along drainage lines;* and also that where efflorescent *reh* is collected in large quantities, and is placed at the disposal as it were of the strong winds of the hot weather, *reh* must be largely dispersed. I have seen frequent instances of the effect of water carried across a *úsar* plain impregnated with *reh*, injuring that portion of the field into which it flows. Last February I was riding back to camp after inspecting a *reh*-infested tract. A strong west wind was blowing, and the whole atmosphere was filled with *reh* particles. This was immediately after I had seen an accumulation of *reh* in the western border of fields lying to the east of *úsar* land white with *reh*, the villagers informing me that the *reh* had been blown thither by the west wind. I can also bear Mr. Buck out when he speaks of land which formerly grew stunted grass, and which is now white with *reh*. Zamindars have often complained to me that land of this description was formerly of some value on account of the pasturage it afforded, and is now good for nothing. This is a very serious matter, for extension of cultivation has very largely diminished the area of the pasture lands, especially of canal-irrigated estates. Mr. Wright in his report on his inspection of the *reh*-affected villages of Sikandra Ráo (letter No. K, dated 22nd March, 1878), states (para. 11) that the severest loss is that of grazing land, which it is almost impossible to estimate.

7. I now proceed to consider how far the conditions under which *reh* is developed are influenced by the introduction of canal irrigation, taking up *seriatim* the questions noted in para. 17 of the *Reh* Committee's Preliminary Report (page iii)

8. First with regard to the extension of *reh*.

A.—Is the introduction of canal irrigation believed to be a principal cause of *reh* extension? Mr. Medlicott points out that where great canals have been led over the face of the country, they have not only altered in a very marked way the level of water in the upper strata, but have also unquestionably introduced an independent and an exhaustible source of *reh*. The more immediate and startling effects have been indirectly raising the water-level over an immense area, and so bringing the under-ground *reh* water more within reach of rapid evaporation; but it is also evident that where the conditions of *reh* formation are set up, *i. e.*, where the removal of soakage water takes place almost exclusively by evaporation, irrigation by canal must end in a destructive crop of *reh*, where the indigenous resources of the ground in that way were comparatively harmless. The

* NOTE.—See map showing *reh* carried by river Nûn for 10 to 15 miles.

process, Mr. Medlicott adds, may be slow according to circumstances, but that it is certain no man in his senses will deny. Mr. Ibbetson states that the Western Jumna Canal was opened in 1820. An irrigation far more extensive than had previously existed was established in 1838, and swamp and *reh* were the immediate results.

Mr. Buck, assuming with Mr. Medlicott that an almost permanent condition of *reh* distribution had been reached in the north of India, observes that on the sudden introduction of a canal system over the face of the country, the underground level is disturbed, the relative positions of *reh* and water are changed, equilibrium is upset, and a fresh activity sets in. The supply of a large body of water brought into close proximity of the surface adds fuel to the evaporating machinery, which is thus enabled to raise larger as well as more exclusive crops of the devastating substance. Mr. Forrest points out that the physical side of the question—that introducing a large body of water into a country, and not drawing on the subterraneous resources as before, will make a change—has been long recognized. He considers that canal water carries *reh* in solution, and also carries it along the surface of the ground, washing it out of its place of formation into good land. (This statement hardly fits in with his assertion in another part of his note, that the canal has never produced *reh* where it did not exist before, or to his reply to question A). Captain Howard is of opinion that the rise of spring-level “in recent years has been caused by obstruction of drainage and by percolation of land water partly from the fields over which it is spread and partly direct from the carrying channels. Any cause which accelerates the rise of the spring-level tends to increase the area of *reh*.” There are, I would observe, in parts of the North-Western Provinces, Oudh, and Panjáb tracts of country in which *reh* abounds in immense quantities. But there the *reh* lands do not increase year by year. We do not hear of their encroaching largely on the cultivated area. The complaints which reach us of *reh* extension do not come from countries irrigated by wells, but chiefly, if not solely, from canal-irrigated districts. Does not this very fact justify the belief that canal irrigation is a principal cause of the spread of *reh*?

9. *B.*—How far is the extension supposed to be due to sub-soil percolation of the water? Mr. Ibbetson holds that percolation from the canal does to a considerable extent take place. He reads the word percolation as I do, *viz.*, “percolation under the surface from the canal and its distributaries, as opposed to saturation caused by actual irrigation, *i.e.*, through water on the surface of the soil. Mr. Buck treats of percolation of canal water in connection with evaporation rather than with raising the water-level. Mr. Ibbetson doubts whether the percolation can be great when the canal is in soil. None of the members of the committee lay any stress on the effect of percolation under pressure, which condemned in the eyes of Colonels R. Strachey, Baird-Smith and Turnbull, canals in embankment which carried water above the level of the country. Captain Howard attributes the rise of spring-level to the percolation of canal water partly from the fields over which it is spread and partly direct from carrying channels. Mr. Forrest does not attribute the extension of *reh* to sub-soil percolation. The sub-soil movements must be slow.

That percolation from canal affects the land in the neighbourhood of the canal, in the form of raising the water-level, is a fact that can hardly be gainsaid. How far it affects the land by bringing with the water particles of *reh* is a more doubtful question.

10. *C.*—How far is the extension of *reh* due to irrigating with canal water? Mr. Ibbetson considers that canal irrigation as practised does more injury than percolation, and that it is the chief cause of the high water-level in canal-irrigated tract. This fact Mr. Medlicott appears to doubt. He contends that if the water did penetrate so easily from the surface, the *reh* scourge would hardly be what it is, as the non-penetration of water is a general accepted condition of *reh* production. Mr. Buck thinks that *reh* is frequently introduced by canal irrigation, as the canal water is brought over soil in which *reh* is deposited, and that canal water adds to *reh* deposit by bringing with it a fresh supply of *reh* from the canal itself. Analysis, he says, may be able to give actual proof of the facts, which it indicates by a scientific examination of the soil of adjacent fields irrigated for a series of years, in one case by well water and in the other by canal water. But analysis will not show whether the presence of *reh* is due to super-saturation or to percolation, or to *reh* having been brought to the land by canal water, unless care is taken to see that the canal-irrigated land is not over-irrigated. Mr. Forrest thinks that canal water may help to distribute *reh* by super-saturation, the water remaining stagnant in the soil and drawing up the *reh* from below the surface by capillary attraction. I doubt whether *reh* is largely conveyed in canal water, but have no doubt whatever that irrigation, especially flush, is so carried on as to inundate the land rather than irrigate it. There are no means available for draining off the superfluous water, which sinks into the soil, and thus adds to the sub-soil water, which is the vehicle for the operation of the evaporative forces which bring the *reh* to the surface.

11. *D.*—How far is the extension of *reh* supposed to be due to the interruption of drainage by canals or distribution channels? Mr. Medlicott regards local obstruction of surface drainage as a secondary influence, and insignificant when compared with the primary conditions at work. Mr. Ibbetson attributes the high water-level in canal-irrigated tracts to the interference with the natural drainage. In Karnal every drainage line in the country is crossed at intervals by high banks. The stoppage of the natural channels by which the surface water should be carried off aids most materially in water-logging the country. Mr. Buck is of opinion that much secondary mischief is caused by water-logging and interference with drainage, which prevents the escape of *reh*-infected water. Mr. Forrest thinks that such obstructions would have an injurious effect if it led to super-saturation. I have frequently seen that, even where canals have been carefully aligned, the *rajbahas* (distributaries) have been taken across the natural drainage of the country. The obstruction of channels, by which the country is drained off its superfluous water, must result in water-logging the soil and raising the water-level, and thus bringing the subsoil water within the influence of capillary attraction.

12. *E.*—What relation (if any) does the extension of *reh* bear to the proximity of a canal or a canal watercourse? This subject has not been

taken up by the members in details. It was decided in committee as to the question—"Has the increase of *reh* been greater near the canal or at a distance from it," that it was difficult to give a precise answer to this question without discussing the conditions of tracts other than that inspected, and that at present it was sufficient to say that no instance is known to any of the committee of serious extension of *reh* at a distance from a canal system. After the committee had broken up, I marched along the Cawnpore Branch of the Ganges Canal in its course through the Mainpuri, Farukhabad, and Cawnpore districts, and rode over much of the adjacent country. The development of *reh* was far greater in the vicinity of the canal and of its distributaries than at a distance. Such was the rule to which, indeed, I saw exceptions. But even in the latter cases it might happen that the land nearer the main canal was less irrigated than that lying alongside a distant distributary, from which water was largely dispensed.

13. *F.*—Is there any relation between the extension of *reh* and the surface level of land affected? I would refer for an answer to this question to the 7th and 8th paras. of Mr. Medlicott's first note (pages ix.-x.)

14. The questions relating to the prevention of *reh* extension will now be considered.

Firstly, *G.*—Is any improvement of drainage desirable? Mr. Michel considers that the one alternative to remodelling the entire canal system is deep drainage; to take and keep down the water to some fixed level; to straighten the natural water drainage channels of the country; to provide embankments with the necessary culverts, and thus relieve water-logging. Mr. Medlicott holds that the one measure that is of obvious necessity under any aspect of the case, and which may be put in hand at once, is *deep drainage*, the original cause of the accumulation of *reh*, whether at or below the surface, being the *stoppage* or the obstruction of the percolation of the atmospheric water from the surface. If the irrigation water is only disposed of by evaporation, it is certain that a crop of *reh* will be the ultimate result of irrigation by canal water, whether by *lift* or *flush* is only a matter of time. *Reh*-charged water being simply the accumulated drainings of *reh* water from the surface, which under proper (natural) surface conditions, for the distribution of the atmospheric water from the ground, would not have become so lodged, this present most abundant source of *reh* might be completely removed by the proper management of drainage cuts. Mr. Ibbetson attaches great importance to keeping the natural drainage of the country open. No dams or cultivation should be allowed in them. The more water we can get to flow away from canal tracts the better, while any *reh* it may carry away in solution is so far a gain. But this evil can always be met by proper alignment of the channels, and by scrupulously keeping the drainage lines open under the Canal Act. The drainages should of course be cleared *from the bottom*, and not from the upper end, as has been done in several instances to the great injury of the people.

Mr. Buck is in favour of *immediate* action for draining such areas as are manifestly swamped by interference with surface drainage, and in which injury is due to this immediately local cause. He looks on a system of very deep drainage as almost impossible. The drainage system must be accessible to the very shallow surface drainage of the earliest rainfall, wherever there is an accumulation of *reh* in the surface. Mr. Forrest thinks that improvement of drainage is always desirable. It is very much to be regretted that the subject of drainage did not receive in the earlier days of canal construction the attention which it now commands. It was the wish and intention of Colonel Cautley, the able projector of the Ganges Canal, that measures for drainage and for irrigation by canal should proceed *pari passu*. Had this been done, the evils which the Government must now cure at any cost would have been prevented. It is sufficient to say that the Canal Department is now fully alive to the evils resulting from the obstruction of natural drainage channels, and that canals and distributaries are now aligned with great care. In Cawnpore the *rajbahas* have been re-aligned. It seems to be quite superfluous to insist on the absolute necessity of taking immediate measures for lowering the water-level in canal-irrigated tracts, in which it has been raised to such a height as to bring the sub-soil water within the grasp of the evaporating forces, the action of which is graphically described by Mr. Buck in the 2nd para. of his note.

15. H.—Is any alteration of the canal system desirable ?

Mr. Michel considers the remodelling of the whole canal system is the only thing that would ensure its being made remunerative beyond any comparison with existing arrangements, while the country might benefit to the extent of double, if not treble. Mr. Medlicott holds that the project of lowering the canal, so as to carry the water everywhere deep in soil, is a move in the wrong direction for a radical cure, inasmuch as the very fact complained of, *viz.*, that the high-level canal forces the *reh*-charged water to the surface, causes the extreme production of *reh* by this very means [see remarks on drainage (G)]. Mr. Ibbetson would distribute water from the canal as at present, *i.e.*, at a high level, and would give enhanced powers to canal officers. He would charge different rates for fields irrigated as a whole and by *kīāris*, and would charge progressive rates for consecutive seasons of canal irrigation. (Mr. Ibbetson is speaking rather of the "system of canal management" than "the canal system.") Mr. Buck doubts whether lowering the canal a few feet would sufficiently curtail the evaporating process. But if he is wrong, he would certainly advocate the construction of canals below, and not above the surface. (This is with especial reference to flush irrigation noticed further on.) Mr. Forrest says the main line cannot be changed. The alignment of distributaries is being improved. I do not consider any alteration (that is, remodelling) of the canal system desirable, for I hold it to be virtually impossible. Even if the idea that swamping and *reh* are mainly caused by percolation under pressure, *i.e.*, that such evils are greater where the canal is in embankment than where it is in soil, were correct, it would be far easier to remedy those evils by efficient drainage than re-align a main line of canal. The last

measure appears to me to be simply an impossibility, except at a most enormous and prohibitive cost.

16. *J.*—Is the substitution of lift for flush irrigation, or any other measure of controlling the surface supply of canal water, recommended ?

Mr. Medlicott treats this subject with the preceding one.—“Is any alteration of the canal system desirable.” He apparently disapproves of the proposal (see para. 15, p. xii.) on the score of the mechanical waste of efficiency. Mr. Ibbetson, on the other hand, lays very great stress on the advantages which would result from the substitution of lift for flush irrigation. He would make the people lift every drop of water they use, water being distributed as before at a high level, but into a small reservoir, from which it would be raised for the irrigation of the field. He observes that such apparently wanton waste of power is of course revolting to the soul of an engineer, but contends that under the flush system economy in the use of canal water is out of question, and that it is the fact that water is lifted up by scoop, the fields are terraced, channels kept in good order, and the severest economy is practised. He further contends by placing a fixed charge per scoop, bucket, or wheel for crop rates per acre (the amount of water that would be irrigated from a single scoop, &c., being practically a constant quantity:), that necessity for half-yearly canal measurements with their attendant annoyances would be avoided. Mr. Buck considers it absolutely necessary to do anything possible to put an end to the vicious system of swamping fields for irrigation purposes, which is the result of the accessibility of flush water. No check is so certain as that of making every cultivator lift his own irrigating water. Mr. Forrest thinks it would be a great economic error; it would throw away a great part of the advantage of the canals. The true remedy is the greater economy in the distribution of the water. The rates of flush irrigation should be raised. Mr. Forrest says very truly that the true remedy is greater economy in the distribution of the water, but this remedy the Canal Department have not yet provided, and, I believe, admit that they are unable to provide. In the absence of the best remedy we must be content with an inferior one. By substituting lift for flush irrigation you substitute perhaps waste of labour for waste of water, and at the same time you diminish the canal revenue, as the flush water-rates are much higher than the lift. But of the two evils waste of water is by far the most serious. It means swamping and inundation in place of irrigation, resulting in deterioration both of the soil and of the health of the people, and eventually in diminution of the income of the people and the reduction of the land revenue, resulting in a loss immeasurably greater than the loss in canal revenue which the substitution of lift for flush irrigation might entail. Waste of power is a far lesser evil. The additional power (that is, labour) which would be required would be supplied from power (labour) now lying idle. The sum representing the difference between the dearer flow rate and the cheaper water rate would purchase that additional power. It cannot be denied that the lavish expenditure (amounting to “wicked waste”) of canal water which the flow system encourages causes excessive saturation of the soil, which is one of the commonest and most powerful causes of *reh* extension.

Until the Canal Department succeeds in securing economy of distribution by giving out their water by measure, the uneducated agriculturist will lay as much water as he can on his field, whenever he can do so without trouble. I think with Mr. Forrest that flow rates should be raised, on the ground that the Government are not getting the proper price for the water. As a remedy against the evils resulting from lavish waste of water under the flow system, enhancing the flow rates will be of no avail. The choice will not be (as far as the people are concerned) between taking water by lift at a cheaper rate or water by flow at a dearer rate, but between taking water by flush or getting no water at all. In short, until canal water is dispensed by quantity, lift irrigation should be substituted wherever it is possible for flow, even if this can be effected only in the mode suggested by Mr. Ibbetson.

17. Before proceeding to discuss the question (lettered K.)—"What experiments or enquiries (if any) should be undertaken with the view of ascertaining the possibility of eradicating *reh* from the *reh*-affected land," I would invite the attention of the Lieutenant-Governor to Mr. Michel's interesting account of the experiments made by him with very great care and under favourable conditions for cleansing and reclamation of certain *reh*-infected land on his estate. Mr. Michel brought his large farming experiences to bear on the experiment, which he carried out at no small cost. For his *modus operandi*, &c., I must refer to his letter of the 14th February last (page iv., &c., of the printed papers). It will be sufficient to state in this place that the result of his experiments was the conviction that surface drainage is not a guarantee against *reh* infection, and that *reh* once fairly developed can never be cured under existing conditions of water-level. Mr. Medlicott takes the same view. He writes: "mere surface drainage is ineffectual for the removal of the highly soluble salts of which *reh* is formed, though they are accumulated at the very surface, the first few drops of rain dissolving and carrying the top soil, where they are untouched by the water draining off the surface. The attempt to make any permanent impression on *reh* ground by any system of manuring or of special crops seems to be hopeless."

18. In regard to the proposals made by the sub-committee, Messrs. Medlicott, Buck, and Forrest, to whom the question of the experiments or enquiries which should be undertaken with the view of ascertaining the possibility of eradicating *reh* was referred, I have only to recommend their adoption. The attention of His Honor is particularly requested to Mr. Medlicott's letter No. 121, dated 6th May (page xlii. of the printed papers).

Mr. Wright's letter of the 22nd March (page xli.) is of interest as describing the actual condition of *reh*-infected tracts. Mr. Wright's local and personal enquiries have proved beyond the possibility of doubt that the water-level has been raised very considerably in the *reh*-infected country he inspected.

In conclusion, I must express my regret that the committee did not meet and inspect the *reh* tract in the Mainpuri and Farukhabad districts, through which the Ganges Canal runs, under the able guidance of that most excellent officer, Captain Harrison, R.E., to whom my best thanks

are due for the assistance he gave me. Mr. Forrest would not then have had reason to notice the small extent of the area affected by *reh*. I saw more *reh* in one day from Bhawant and Dbaros in the Mainpuri, and Baghosi and Aima in the Farukhabad district than I should have seen in ten days in that part of the Aligarh district which was visited by the committee.

The 26th September, 1878.

H. S. REID.

Preliminary Report of the Committee appointed under G. O. No. 98A., dated 30th May, 1877, for investigating into the causes of deterioration of land by reh in the Aligarh district.

1. THE committee assembled on the 15th of February at Akrabad, and an inspection of the villages most affected by *reh* was made on the 16th, 17th, and 18th of February, after which, by direction of the President, the following questions were placed before the committee with the special reference to the *reh*-infected tracts which had come under inspection, with the view of placing on record as far as possible the results of the local enquiry and investigation made by the committee :—

- (a.) Has the water-level risen, and to what extent?
- (b.) Has the increase of *neh* been greater near the canal or at a distance from it?
- (c.) Has the efflorescence of *reh* increased in tracts affected before the construction of the canal (e.g., in *usar* plains)?
- (d.) Where *neh* has extended in cultivated land, is it always or usually in proximity to land previously affected?
- (e.) Is there any connection between *reh* extension and natural drainage?
- (f.) Is the spread of *reh* more marked where drainage is obstructed than elsewhere?
- (g.) Are there any instances, and are they numerous or not, of *reh* spreading by shallow surface drainage, i.e., by being washed from a *reh*-affected area of land to an area not before affected?
- (h.) Are there any instances in which *reh* appears to have extended by the action of the wind?
- (i.) Are there any instances in which *reh* extension appears to owe its origin to well water?
- (j.) Are there any instances in which *reh* extension in cultivated land appears to owe its origin to *reh* brought by irrigation passing over *reh*-affected land?

2. The following questions of a general character, i.e., of which the answer need not have special reference to the tract under inspection, were, by direction of the President, next placed before the committee :—

- I.—To what causes does the extension of *reh* appear to be due?
- II.—What measures are suggested for checking the further extension of *reh*?
- III.—What measures are suggested for curing land already affected by *reh*?

3. The first series of questions (a) to (j), referring specially to the tract under inspection, were discussed in committee and the following answers recorded :—

- (a.) *Has the water-level risen, and to what extent?*

The committee could at present only place on record the fact that enquiries from cultivators induce the belief that there has been a considerable rise. They desired that Mr. Wright, the settlement officer now in the district, should be asked to record the present depths of wells in all the villages of the tract, and that he should obtain any figures procurable from old settlement records as to their former depths, and submit them to the committee; also that the local canal officers should be asked to furnish any statistics of well depths available from the records of their offices.

Some measurements were made by members of the committee, from which it was evident that water was within a few feet (generally eight to twelve) of the surface.

Preliminary report.

4.—(b.) *Has the increase of reh been greater near the canal or at a distance from it?*

It is difficult to give a precise answer to this question (one specially put by Government in G. O. No. 688A., dated 20th April, 1877) without discussing the condition of tracts other than that inspected. At present it is sufficient to say that no instance is known in the experience of any of the committee of serious extension of *reh* at a distance from a canal system.

5.—(c.) *Has efflorescence of reh increased in tracts affected before the construction of the canal (o.g., in úsar plains)?*

Mr. Smith, who inspected this tract for purposes of settlement about seven years ago, states that he has noticed a great increase in surface efflorescence since he first visited it. Cultivators and zemindars universally testify to the same fact, and describe areas of land now white with *reh* as having been covered with grass.

6.—(d.) *Where reh has extended in cultivated land, is it always or usually in proximity to land previously affected?*

As a rule, *reh* appears to have extended within the tract under inspection in proximity to úsar plains or old sources of *reh*, but contact with them does not seem to be a necessary circumstance.

7.—(e.) *Is there any connection between reh extension and natural drainage?*

The committee were of opinion that the spread of *reh* occurs more often and more conspicuously in proximity to natural drainage lines, but that it does not necessarily always appear in connection with them. Mr. Forrest, however, was inclined to believe that a connection always existed. The above statement refers only to the tract that came under inspection. Connection of *reh* with drainage will be considered more fully as a general question.

8.—(f.) *Is the spread of reh more marked where drainage is obstructed than elsewhere?*

The committee were unanimous in considering that obstruction of natural drainage, although not necessary to the development of *reh*, yet always, within the tract under inspection, tended to produce a conspicuous increase.

9.—(g.) *Are there any instances, and are they numerous or not, of reh spreading by shallow surface drainage, i.e., by being washed from a reh-affected area of land over an area not before affected?*

The extension of *reh* has been, in the opinion of the committee, assisted by the above process; but although instances of such action appear to have been numerous, yet the individual areas thus affected have been small.

10.—(h.) *Are there any instances in which reh appears to have been extended by the action of the wind?*

The committee cannot generally affirm that they have seen any such case, but Messrs. Forrest and Buck believe that some cases of extension are due to *reh* blown from a *reh* plain over cultivated land.

11.—(i.) *Are there any instances in which reh extension appears to owe its origin to well water?*

Several cases of well irrigation occurred within this tract. The committee could find no decided instance of *reh* extension due to well water.

12.—(j.) *Are there any instances in which reh extension in cultivated land appears to owe its origin to reh brought by irrigation passing over reh-affected land?*

Some of the committee consider this circumstance to have been a minor cause of *reh* extension.

13. The above questions refer to the special tract under inspection. It may be noted here that specimens of soil and water from certain selected localities, which will be described hereafter, were collected by Mr. Medicott for analysis, with the view of ascertaining the percentage of *reh* contained in soil at different depths and in water underlying soils affected in a greater or less degree by *reh*.

14. The statistics of areas of cultivation affected by *reh* since the settlement of the tract will be furnished by Mr. Wright, settlement officer, who is completing and testing the detailed field survey set on foot by Mr. Buck.

15. The general questions marked I., II., and III., referring—

I.—to the cause of *reh* extension,

II.—to its prevention,

III.—to the cure of land already infected,

were then placed before the committee.

16. With reference to these questions it was found impossible to record any unanimous opinion. After some discussion it appeared to the president desirable that a deliberate expression of the views held by each member of the committee should be placed before him, the submission of which is now awaited.

17. The president has desired that the following questions should be specially considered in the notes by the members of the committee:—

Under I. (1.)—Is the introduction of canal irrigation believed to be a principal cause of *reh* extension?

(2.)—If so, how far is the extension supposed to be due—

(a.)—to subsoil percolation of canal water.

(b.)—to irrigating with canal water.

(c.)—to the interruption of drainage by canals or distribution channels.

(3.)—What relation, if any, does the extension of *reh* bear to the proximity of a canal or a canal watercourse?

(4.)—Is there any relation between the extension of *reh* and the surface level of land affected?

Under II. (1.)—Is any improvement of drainage desirable?

(2.)—Is any alteration of the canal system desirable?

(3.)—Is the substitution of lift for flush irrigation, or any other measure of controlling the surface supply of canal water, recommended?

Under III.—What experiments or enquiries, if any, should be undertaken with the view of ascertaining the possibility of eradicating *reh* from *reh*-affected land.

18. Under the last head (III.) it was decided by the committee, with the concurrence of the president, that proposals as to the form which experiments or enquiries might take should be referred to a sub-committee composed of the following members:—

Mr. Medicott, | Mr. Forrest, | Mr. Buck,

who should be called upon for a special report after review of the notes submitted by the members of the committee.

19. The whole proceedings will then finally be placed before the committee and submitted with their recommendations to Government.

20. A copy is appended of a letter by Mr. Michel, indigo planter in the Meerut district, who was under the instructions of Government consulted by the president. The letter was read before the committee, and referred to experiments of considerable interest. The thanks of the committee are due to Mr. Michel for this contribution.

21. On the adjournment of the committee by the president, Messrs. Medicott and Buck proceeded to Mr. Michel's estate in the Meerut district, and the result of their inspection will be recorded in the notes submitted by those members.

Note by J. MICHEL,
Esq.

22. Mr. Ibbetson, the settlement officer of Karnál, produced some valuable evidence connected with the extension of *reh* in that district, which he has been good enough to promise to embody in the note to be submitted by him.

The president desires that Mr. Medlicott be thanked for the readiness with which he has undertaken the troublesome analysis of so many specimens of soil and water.

Dated 13th March, 1878.

E. C. BUCK,
Secy. to the Reh Committee.

Dated Mussooree Factory, the 14th February, 1878.

From—J. MICHEL, ESQ., Indigo Planter, Dasna, near Gháziabad,

*To—H. S. REID, ESQ., Senior Member, Board of Revenue, N.-W. P., and
President, Committee on Reh.*

SIR,—As I believe I shall best meet the wishes of the Lieutenant-Governor and the object of this committee of enquiry by a short *précis* of my experiments for the cleansing and reclamation of *reh* lands, I will first state what I have done in that direction, with the results.

2. In January, 1867, I began on a small section of the Dasna estate a system of surface drainage to facilitate the washing off of all *reh* deposits within that area, which being completed, I selected a sloping field having a good outfall, in which *reh* was then fairly shown as efflorescent.

3. This field is about 800 feet from a rájbaha which carries a large volume of water, some five feet above the level of the field, which itself slopes freely with a fall of about 18 inches in its length, and an outfall into a drain dug along its lowest boundary to a depth of about 3 feet, leading into a larger arterial drain having a good fall throughout to the boundary of this estate.

4. I then flooded this field in sections, banking up its lowest edge with earth dug from the lower depths of the drain, scouring off the surface by several simultaneous cuts into the drain, and repeating the operation two or three times before proceeding to the next stage of this experiment, *viz.*, ploughing to a depth of not less than six inches by five repeated ploughings. Another flooding was then tried, and when run off and dried there appeared (much to my vexation) quite as active a process of efflorescence going on as before we began operations.

5. Another flooding was then tried, and as soon as practically fit, the land was ploughed up and fully three inches of indigo trash laid all over the surface, presenting the appearance of a great black carpet; this was then ploughed in thoroughly, and rather more than an average dose of village (khat) manure deposited on that and ploughed in well; the land being thus prepared for the indigo seed which I intended to put in was left ready for use.

6. In April the seed was sown after slight irrigation, and germinating freely (much to our satisfaction), a fair crop was expected. A second watering, however, began to bring out the really intractable nature of the soil; small scabby little patches of burnt plant showing within a few days. A third watering increased the evil, and before the rains set in there was not a vestige of the crop to be seen.

7. The idea suggested itself that not sufficient moisture had been left in the land in the intervals of watering, the plant showing symptoms of languishing before it was re-watered; each watering being followed by a slight though clearly marked whitish-brown efflorescence on the soil, and I then determined to renew the experiment next season with other materials, and on a somewhat different plan; noting, however, that although the rains had been very unusually heavy, the appearance of this field, well drained and well scoured as it had been by its natural slope and specially prepared drainage, was really no better, if no worse, shortly after the rains had ceased.

8. Before, however, giving it up in its then condition, I had all the loose top efflorescence swept off into the drain, a light watering given, a dose of fresh indigo trash of the season just finished laid on and ploughed in, and the usual quantity of barley seed sown per bigha. This in a short time came up fairly, but as soon as the waterings began, decayed and died off as the indigo had done before, though kept fairly supplied with moisture and drained of all excess (as before).

Note by J. MICHEL,
Esq.

9. My next year's experiment was begun stage by stage, as before, adding a layer of silt about three inches in depth, which was served over with indigo trash, and "khat" ploughed into it and indigo seed sown again; germination was rather slow, attributed to the coldness of the silt on the surface. The crop, however, gave great promise for a time, but as the rains set in, when we hoped to see it spring up, as indigo usually does under their influence, the crop steadily declined, and after the first few showers but a few stalks remained to show a crop had been there, not a single plant coming to maturity.

10. After again trying a rabi sowing in the end of 1868 (putting in only khat again, with precisely the same result as before), though much disheartened with it, and seeing that some parallel experiments on a smaller scale with a variety of manures tried singly (in one instance only indigo trash, in another only fresh cowdung, in a third only fresh stable manure, in a fourth the sweepings from my sheepfold and poultry yard) had all signally failed to produce the least improvement or satisfactory result of any kind, beyond that of a fair show of germination, in some cases with a shorter or longer interval preceding decay, I determined on giving a fuller trial to the theory then dominant among canal officers, that silt, and silt alone (as had been proved somewhere in the Etawah district, it was said), was all that was necessary to cure *reh*, I spent a large sum of money and employed a number of carts for months to cover over several large areas with silt under varied conditions of slope, elevation, drainage, and efflorescent deterioration, again experimenting (in 1869) on the original field with more than a foot thick of indigo trash laid all over the soil and burnt, so as possibly to destroy the top layer of soil impregnated with the saline poison; then dividing it into four sections, taking off the burnt surface in one section by sweeping and flooding, manuring it well afterwards; in the next section ploughing the surface into the land, covering it over with silt in the third, and ploughing it all in together, and treating it well with mixed manure in the fourth; thus hoping to arrive at some result through the action of fire; the land itself, I would remind you, still showing not one whit of real improvement or change in any particular, for all that had previously been done to it.

11. All these experiments, carried out with the greatest care and perseverance, giving practically no other results than all the foregoing, has firmly convinced me:—

12. *That reh once fairly developed can never be cured under existing conditions of water level.*

13. Constant fresh applications of soil and manure may keep it down, or, in other words, may build over it a false top soil, which I can show in some instances done with temporary success; but to cure *reh*, under existing conditions, with any prospect of return from the land commensurate with the expense, is in *my experience* utterly impracticable.

14. I may now state the result of my observations on the well-known increase of the deterioration of soil in canal districts as evidenced by the extension of *reh* deposits;—

First, that its first indication in irrigated cultivation is a marked change in the colour of the soil, which, though with a crop on it, will after a slight fall of rain, or a watering by either well or canal, show faint but distinct lines of a pale orange-red oxide on the slopes of every little hollow or indentation which has held water. To this succeeds, it may be in a year or two (more, no doubt, in some cases), distinct patches of a few square yards only; oftenest *slight elevations* of a pale grey colour that

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the young crop is dying off, and *that* markedly during a dry cold rabi. These patches extend slowly but surely, depending, 1st, on the normal quality of the soil; 2nd, the relative level of the field; and 3rd, its proximity to the canal and large rájbahas which maintain the process of saturation.

Second, that no soil, but possibly bhúr (?), is proof against its deposition, and *that* one only, I believe, when in well-drained ridges

Vide page 6, queries and replies,
Mr. Barstow, Deputy Collector,
Etáwáh.

too high to be affected by the rise in the spring level,

as mere surface drainage will not check it; and where

Vide page 8, queries to Mr.
Halsey, Collector of Cawnpore,

not so, reh will be deposited on it as well as other soils in this climate under saturation.

Third, that *reh* in the vicinity of either block kankar or brick masonry walls (not vitrified material) as rapidly eats into them as the smoky atmosphere of large cities in Europe destroys the best stone structures exposed to it, both being the result of analogous chemical combinations, varying in their formulation between the production of sulphates, carbonates, muriates, and nitrates of alkaline metallic bases, the latter of which I believe to be the most intractable, because, like the well-known "dhoak" of the saltpetre manufacturer, they regenerate and renew themselves with great activity and increasing power of absorption from the atmosphere on the merest trace of humidity.

15. A score of *formulae* might, I think, be safely advanced to account for the deposition of *reh* so-called; any one of which could, I believe, be sustained by analysis of the varieties found in comparatively close proximity to each other, dependent on the varied constituents of the soils on which they are found, and the variety of organic and inorganic matters brought in contact with them in their nascent form; not to lose sight of the powerful effect of electrical action during thunderstorms in such heated atmospheres; its rapid evolution of charges of nitric acid readily absorbed by the super-saturated soil, while the glaring sunlight alone is sufficient to effect the transformation of the most powerful re-agents ready to hand under the desiccating heat of these provinces and its power of evaporation.

Fourth, that the presence of *reh* is, without exception, an indication of a kankar formation of greater or less density at no great depth, though I certainly do know that the reverse position is to be met with, kankar below the soil not being always overlaid by *reh*. But from observations on tracts under this condition, I am of opinion that where this does exist, and the kankar is not removed, free drainage not being provided, the soil will become *rehlic* in course of time; the removal of kankar then might be supposed as a corollary to free the land from this contingency where it already exists, and thus dispose of the evil by checking the fount of its most general production; but, as I have said above, "*once reh, always reh!*" At least so long, and as frequently, as that one condition of supersaturation of the soil alone affords the ready medium of developing its production in one form or another, and until that is removed, all experiment is useless, and all argument reduced to mere speculative hypothesis.

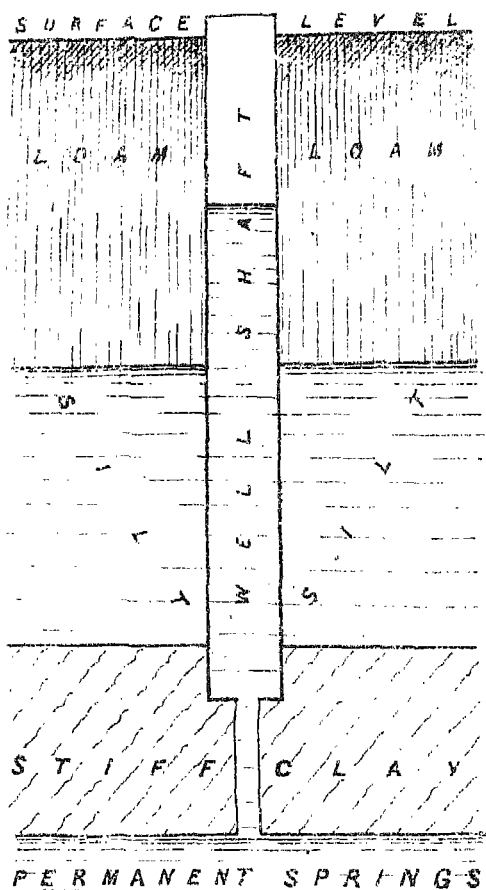
16. Acknowledging receipt of "correspondence published in 1864," relating to the deterioration of lands in the districts irrigated by the Western Jumna Canal, the whole subject of *reh* supersaturation, and the constituents of both soil and water, has been so thoroughly exhausted, and the radical cure so conclusively established, *viz.*, low level irrigation or irrigation by lift, that I feel it would be mere effrontery on my part to attempt to offer any new suggestions for the alleviation of so great a scourge as besets high level canal irrigation in these provinces, the evils attendant on which could not have been more graphically described, if meant to have been applied to them.

17. Surface drainage, you will observe, had there been put forward as an effective palliative; but before your committee accept of this as a guarantee against future loss, I would invite their attention to the fact that a complete system of surface drainage in perfect operation for the past eight years has in no way checked the evil on

these my estates, unusually well provided though they are with tons of manure and cattle labour from within and without, and displaying among the tenants a willingness to take full advantage of the facilities provided for both transit and drainage to an extent not frequently met with.

Note by J. MICHEL,
Esq.

18. I would also urge on their consideration the faint utility, if not rather the probable mischief, of the proposed palliative of supersaturation—" *extensive well irrigation* "—not alone, because so far beyond the scope of individual proprietors to establish,



but seeing that the very existence of wells and their freedom from impure supplies must depend on the perfect shutting off of all superincumbent percolation overlying the stratum of clay, from beneath which only pure unimpregnated water could be obtained (*vide sketch*); their effect would be absolutely negatived, or rather an aggravation of the evil, merely in fact adding to the already supersaturated crust above by pouring in supplies drawn from springs below, which cannot in any degree afford relief to the saturation (now freely admitted), whether caused most by irrigation or percolation seems to be mere waste of time and argument to determine.

19. There is, then, but the one alternative to remodelling the entire canal system, and that is DEEP DRAINAGE, to tap and keep down the water to some fixed level.

20. The question to be dealt with is the quantity of water to be disposed of, obviously just as much as delivered by the canal in each section of its length; noting then the consumption of water

from the canal between each natural drainage head in its course through the Duáb; let deep channels be dug and these natural courses improved to carry off the required volume, and something more now, to give us speedy and permanent relief.

21. In short, let every nála be straightened out in its course as far as practicable, and every natural watercourse to it made as direct as the country it relieves will admit of, and thereby lowered to its greatest slope; and let every embankment be provided with its necessary culvert, proportioned to the section embanked across, as it clearly should have been originally, and but a short period would relieve the Duáb of this scourge of water-logging, the canal itself being then fairly utilised to wash away the accumulations of *reh* from the surface. Something might then be done by careful experiment, under scientific observation, to restore the lands already destroyed, but which, so long as the cause of their deterioration is still in active operation, cannot be tried with any chance of success, and must merely add to the burden and waste of public money in a direction already too embarrassing to be longer ignored with impunity.

22. A scheme for remodelling the entire canal system is obviously so thoroughly a professional subject, that I may be pardoned entering upon it without some more direct invitation; though I may take this opportunity of saying in the best interests of the State and the community to which I belong, that I believe it to be the only thing that would ensure its being made remunerative beyond any comparison with existing arrangements, while the country might benefit to the extent of double, if

First Note by H. B.
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not treble, the area secured against all contingencies of drought, and a spirit of self-reliance again awakened among the peasantry, now demoralized and sunk in apathy, confident that as the Sirkár has brought about the condition of which they recognise the worst features, but with a helpless feeling of indifference, it is to the *Sirkár* they will look for every want, idly witnessing the spread of epidemic disease, the decay and deterioration of both soil and animal life among them, without an effort to make it known, content to take all they can out of the soil, in the hope that as it stood their fathers in stead before them, it will at least last out their day and generation.

23. With a regret that I have been unable to join your committee in person, I submit these facts and observations for the consideration of your committee.

Note by H. B. MEDLICOTT, Esq., Superintendent, Geological Survey of India.

EVERY opinion upon the extension of *reh* involves some assumption as to its mode of origin, and it is obvious that the only safe way to arrive at a cure, or a prevention of the evil, is to ascertain how it comes to be formed. Without this knowledge, an apparent remedy may be the surest way to intensify the disease in its worst form. It seems to me that the facts in hand admit of a correct view of the mode of production of *reh*, and suggest the only means for its removal or prevention. So much misapprehension exists on the subject, that I must be pardoned for going into some elementary details.

2. *Reh* is formed of highly soluble sodium-salts, the result of the decomposition, by air and water, of the particles of rock-minerals to be found in almost every soil; and thus *reh* itself occurs very generally in soils, being the waste products of soil-formation—the elements unassimilated by vegetation—the gradual removal of which is (or should be) effected by the rain water draining through the soil and carrying with it any excess of these highly soluble salts. In this way all subsoil drainage water contains *reh*, while mere surface drainage water contains little or none, but only matter in mechanical suspension; and thus it is that rivers in flood contain less dissolved matter than in dry weather, when fed chiefly by percolation water.

3. The fact last mentioned points to another important factor of the problem before the committee: that canal water, being to some extent subsoil drainage water, must contain *reh*; and that it does so has been pointed out by every one who has analysed the water with reference to this question; by Dr. O'Shaughnessy in 1850, by myself in 1861, and by Mr. Ward in 1869. The importance of this factor will be apparent when the other conditions of *reh*-formation are considered, and the persistent denial of it by canal officers is an infatuation.

4. It is evident that salts of this nature cannot be exhibited in the presence of water, as they become at once dissolved by moisture; and thus they cannot be visibly accumulated in ground to which water has access. Apparent exceptions to this statement have been noticed, where a band of *reh* is seen on the face of a steep ravine or drainage cut; but I have always found that this is only the outcrop of a more porous layer, at the exposed surface of which a prolonged evaporation is sustained by the settlement of subsoil water, whereby an accumulation of the salts takes place at that surface. All completed observation has shown that the amount of *reh* in the ground is not as a whole excessive; and that the possible increase to it, from purely local causes, is also strictly limited by the small proportion of alkaline bases still locked up in other combinations, and which can only be liberated by a very slow process of decomposition.

5. I pointed out years ago that a highly fertile soil in a temperate climate may contain more *reh* than is sufficient to produce a barren *reh* soil under certain conditions in India. This fact at once suggests that climatal conditions have much to say to the evil complained of. The same is apparent from observation in India itself: within the continuous area of the Indo-Gangetic plains, it is only in the

scorching climate of the north-west that *reh* has become a scourge. It is quite certain that evaporation is the immediate cause of its appearance as a white crust on the surface, and that its concentration there is the efficient cause of ruined vegetation. I have shown that where the surface soil contained 40 per cent. of *reh*, the subsoil at 2 feet contained only 0.17, and at 4 feet only 0.14—quantities well below what might pass as a normal element of the earth. Evaporation being thus the immediate developer of *reh*, and water in the soil the necessary vehicle for this operation, the conditions of the water circulation on, in, and under the soil become a main feature of the whole question. Unfortunately, this condition is somewhat occult, being rarely open to direct observation on an effective scale, or even depending on characters not at once apparent to the eye when seen; and, accordingly, some rather arbitrary suppositions have been hazarded upon this point of the enquiry. The feature can only be fully appreciated through geological considerations; but it will probably be admitted by all that we have to deal with a great spread of deposits of variable composition and texture, and correspondingly unequal in permeability to water. The arrangement of these materials being in more or less horizontal strata, the diffusion of permeating waters must invariably take place in these planes. This is illustrated by the observation already quoted, of bands of damp surface or of efflorescence on the face of steep bare sections; and again, in a very pertinent manner, by the fact that within and near *reh* areas the upper water stratum is usually saline, a lower one being sweet.

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6. As a geologist I cannot forbear here to mention an argument of much force to those who accept such evidence: all we know regarding these beds suggests that they are purely fluvial deposits, such as are still in progress of formation in the lower areas of the plains, and that like these they were originally deficient in saline matter, instead of being, as now, more or less pervaded by salts. If this opinion be correct, we must in a measure invert the *prima facie* view of the position, and account for the origin of the saline water stratum by the underground storage of *reh* water from the surface. The rational interpretation of all the facts, so far as known, seems to require this supposition.

7. The apparent capriciousness of the distribution of *reh* has greatly obstructed a right comprehension of its mode of production, by giving a superficial objection to each influence assigned; although most prevalent in connection with swamping, *reh* may also be found where there is no lodgment of water, and where the underground water-table is far from the surface; if canal water is accused of contributing to the *reh*, the practical man assures us that this water is practically pure and harmless, that *reh* is found where the canal has never extended, and that *reh* has not appeared in some places where the canal water has been long in use. Again, on the same even surface, level, or sloping, with no visible difference in the soil, *reh* often shows itself most irregularly, bald patches in the midst of cultivation, or cultivated patches surrounded by *reh*; sometimes the efflorescence is strongest in the slight depressions, sometimes in the slightly raised areas.

8. Whatever secondary causes there may be to aid in complicating appearances, such as the very local surface-washing from one area to another, I know of no cases of *reh* that may not be due to the primary conditions already indicated, which may be comprehensively expressed as *defective water circulation*. From the farmer's point of view it would be desirable to pass all the rainfall through the ground: any nutritious element in it would be retained in the soil, and any excess of soluble elements in the soil would be carried off. Unless this process takes place to a certain extent in every soil, injury must ensue according to circumstances; and in Upper India these circumstances end in *reh*. Owing to shallow cultivation and the total absence of forest vegetation, the rain falls upon a bare, hard, impervious surface; so far as the slopes admit, it runs off rapidly to the natural drainage courses, but much of it remains covering shallow depressions with great sheets of water. Although the

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ground is parched after the fierce heat of the early summer, comparatively little of this surface water is absorbed, quite insufficient to establish the needful partial escape by underground drainage, and so it remains to be withdrawn by evaporation, leaving all the soluble matter at or near the surface. The chief effect of this unnatural process is found near where the water lodges, where the greatest amount of evaporation takes place at a surface supplied from a shallow water-table; but a similar result may occur at any elevation, wherever the whole of the water soaked during the rains is withdrawn again by evaporation. That such cases can occur is sufficient proof, and it has also been shown experimentally that mere surface drainage is ineffectual for the removal of these salts, although they are accumulated at the very surface: the first few drops of rain dissolve and carry them into the top soil, where they are untouched by the water draining off the surface. The apparently capricious distribution of *reh* over a uniform surface does not imply a greater amount of *reh* in the ground under that surface originally, but only that more evaporation has taken place there, owing to a freer supply of soakage water, this condition being determined by original differences of texture in these old alluvial deposits; a very little more or less of clay, quite inappreciable to the eye, in different layers or in different parts of the same bed, would quite account for the very irregular appearance of the efflorescent *reh*, and the peculiar aspect of an *úsar* plain.

9. By the operation of these conditions a permanent equilibrium of *reh* distribution would in time be established; the limit of fresh *reh*-formation would be slowly attained, and these very slight additions from local sources would be disposed of, as before, according to position. Such a state had in fact been approximately established; the great *úsar* plains have existed from unknown times; and the only changes naturally possible would be from fluctuations of rainfall and heat. In this way, no doubt, new *reh* land might be formed by the stoppage of some remnant of underground drainage; but extension from this cause would be very restricted. The state of things thus brought about was bad enough, and may be confidently ascribed to the subversion of the primitive natural conditions of water-circulation and climate, through the wholesale destruction of forest vegetation, the influence of which is to distribute moisture at and below the surface, and to moderate the action of the sun's heat. The effects were not confined to the surface: the access of rain water is the necessary condition of the renewal and purification of the upper water stratum; but under the perverted circumstances of the surface, only small dribblets of the impure subsoil water could get through, and the result has been the pollution of this most accessible source of water-supply over very large areas, and, in some cases, to a great depth. In a trial boring for a well, recently made in the Hissár division, saline water was found to a depth of 500 feet; but throughout the Duáb sweet water may be counted on below sixty feet from the surface. This is the worst aspect of the *reh* question: we have not only to deal with a certain amount of *reh* in the soil, but also with *reh* water largely accumulated in the upper water-bearing strata. It is evident, however, that even this condition might attain a permanent state compatible with cultivation if external sources of *reh* were excluded, and with a sufficient renewal of rain water to keep the saline water within a certain point of dilution. In this way irrigation with more or less damaged water has been going on for long in many parts of the country: whilst the soil is kept damp, the *reh* remains diffused, and vegetation is possible.

10. External sources were not, however, excluded, great canals have been led over the face of the country, and besides altering in a very marked way the level of the water in the upper strata, they have unquestionably introduced an independent and an inexhaustible source of *reh*. The persistent denial of this fact by the canal officers is a sufficient revelation of the kind of study this important question has received at their hands. It is true that the more immediate and startling effects have been indirect, by raising the water-level over an immense area, and so bringing the underground *reh* water more within reach of rapid evaporation; but it is quite

evident that where the conditions of *reh* formation are set up, *i.e.*, where the removal of soakage water takes place almost exclusively by evaporation, irrigation by canal water must end in a destructive crop of *reh*, where the indigenous resources of the ground in that way were comparatively harmless. The process may be slow, according to circumstances, but that it is certain, no man in his senses will deny.

First Note by H. B.
MERRICOTT, Esq.

11. In the foregoing considerations I have ignored all secondary influences, such as the local obstruction of surface drainage, or the possible spread of *reh* by rain-wash and wind-drift, because they are insignificant when compared with the primary conditions at work, and any efforts directed against them can only be partial, and would divert attention from the real sources of an evil that threatens to convert Upper India into a howling wilderness. In the face of such an evil it is distressing to have to insist upon measures that seem almost impracticable under the circumstances of agriculture in India; but it is always right to indicate the best course to be followed, and only to depart from it of necessity. In the first place I must notice the immediate active cause of the mischief, the extreme climatal conditions of the area affected, the scorching sun's heat, and the desiccated hot wind from which the ground has no protection. The only way of mitigating this cause is by the extension of forest cultivation. The need for this has been repeatedly urged, from various points of view; the neglect of it in this case may even frustrate the best efforts to counteract the evil through the other conditions of *reh* extension.

12. The immediate condition for the injurious action of the atmospheric heat is the intractable state of the surface-earth. If a sufficient proportion of the rainfall sank through the soil, and the subsoil water were thus sufficiently replenished to ensure a sufficient escape and renewal to maintain its moderate purity, the conditions for cultivation would still be in working order. Unfortunately the several terms of the question indicated here by the word 'sufficient' are undetermined quantities, and they would evidently rise in proportion to the severity of the active cause, whereas in point of fact the rainfall must diminish with the increase of heat at the surface of the ground. It is thus apparent that a state of things might ensue, such that no manipulation of the subsequent rainfall would suffice to arrest the progress of destruction. The only way to effect the penetration of water from the surface is by deep cultivation, aided, when necessary, by subsoil drainage. With the Indian cultivator this seems an impossible remedy: it may, nevertheless, be the only one. I have heard of no established objection to its efficacy in the case under notice. A dry open soil will absorb about one-half its bulk of water, and it would be far less subject to the influence of heat than a soil compacted into a brick-like consistency.

13. It is in connexion with canals that this question assumes its most pressing aspect; and, no doubt, the facts are very alarming. The committee has seen large tracts now quite barren which were fertile fields at the time of the late settlement: and the damage is far greater than would appear from official returns, in which only cases of complete ruin are brought to notice. I have since seen a large area in a district supposed to be generally free from *reh*, but where the evil is already in an advanced stage of progress, showing frequent large blotches of feeble vegetation, and having strongly saline water within six feet of the surface, brought up to this level by the influence of the canal. I have been told (by canal officers) that there are places similarly almost swamped by canal water without any symptoms of *reh*. I am disposed to question the completeness of the observation, but even if correct, it would only imply that there the subsoil drainage was naturally thorough, so that although the same evaporation must go on, the freshness of the water is maintained by constant removal and renewal.

14. Next to the extravagant proposal to close the canals, the most extreme measure suggested, and the one most generally advocated, is to remodel them so as to carry the water everywhere deep in soil. Being thus brought much nearer to the natural level of the upper water-table, the effect of the canal water in raising that

First Note by H. B.
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level, to which action so much damage is naturally attributed, would be greatly reduced; irrigation by lift would then also take the place of flush irrigation, and so a great deal less water would be used or wasted. The most pressing cases of actual destruction from *reh* are so obviously connected with the raising of the water-level in connexion with the canal, that the plan of lowering its level recommends itself to every one but those who understand the immense cost and difficulty of carrying it out. This difficulty is, however, only a collateral objection; a more real objection lies in the doubtful efficacy of the measure. It would indeed reduce the progress of *reh* formation in many places; but there is imminent risk that it would fatally diminish our power to deal with the evil as a whole, and so hasten or even produce the final catastrophe.

15. The mechanical waste of efficiency involved in a return from flush irrigation to irrigation by lift was aptly compared by a member of the committee (Captain Howard, R.E.) to that of a return from breech-loading to muzzle-loading firearms. But as bearing upon the *reh* question, the objection to the project of lowering the canal is, that not only it is clearly a partial measure, not aimed at the real source of the evil, but that it is a move in the wrong direction for a radical cure. The very fact complained of, that the high-level canal forces the *reh*-charged ground-water to the surface, and so causes extreme production of *reh* in certain positions, is in itself a most hopeful symptom of a possible cure by this very means; for that *reh*-charged ground-water has no business there; it is simply the accumulated drainings of *reh* water from the surface, which under proper (natural) surface conditions for the distribution of atmospheric waters through the ground would not have become so lodged, and that the canal thus compels it to move on is a strong hint that, by the proper management of drainage-cuts, this present most abundant source of *reh* might in this way be completely removed. If the upper ground-water at a moderate depth from the surface could be kept nearly as pure as canal water, the dangers to be feared from *reh* would be greatly reduced. Irrigation under any system cannot be in a healthy state while the upper ground-water is so generally polluted; and the best hope of purifying this is in having command of water at a high level.

16. When we consider the original cause of the accumulation of *reh*, whether at or below the surface, namely, the stoppage or the obstruction of the percolation of atmospheric water from the surface, the project of lowering the canal level seems equally doubtful; a free supply of water at the surface being one of the obvious conditions of cure. The removal of that stoppage or obstruction is, however, a prior condition to be fulfilled. Unless the ground is prepared to absorb the water, and pass on a certain portion of it, the free use of canal water will only aggravate the evil. Unless this condition be fulfilled, *i.e.*, if the irrigation water is only disposed of by evaporation, it is as certain as the multiplication table that a crop of *reh* will be the ultimate result of irrigation by canal water, whether by lift or by flush is only a matter of time. To any one who perceives that this treatment of the ground is an essential feature of the *reh* question, the difficulty of obtaining it under the circumstances of agriculture in India is profoundly affecting, suggesting as it does the certain deterioration and ruin of vast tracts of country. If this condition were impracticable, one would have to accept the total stoppage of canal irrigation as ultimately the lesser evil, for the same result could never come about from rain water only, although the aggregate of misery from the recurring failure of the rain supply might be as great.

17. The one measure that is of obvious necessity under any aspect of the case, and that may be at once put in hand, is deep main drainage. It would certainly alleviate the evil in what are at present the most threatening cases, and it would also be a necessary feature of any general scheme of improvement.

18. The attempt to make any permanent impression on *reh* ground by any system of manuring or of special crops seems to me hopeless; but I consider that an

adequate experiment should be made upon *reh* ground with subsoil drainage, deep tillage, and canal irrigation.

First Note by D. IBBETSON, ESQ.

19. As having an important bearing upon the question of the origin and distribution of *reh*, as well as upon measures of prevention, I would strongly recommend that a water map should be prepared of each district in the Duáb, *i.e.*, a map on which every well should be marked, with the elevation of the ground above the trigonometrical survey datum, the maximum and minimum depth of the water from the surface, and the total depth of the well. As great accuracy would not be required, such a map might be easily prepared by reference to the canal bench-marks. A rough *reh* map of each district should also be made, showing approximately in two shades ruined land and affected land. That these maps should be comparable, they should be tested by the same competent officer.

20. One of the most essential items of information in connexion with any scheme for the prevention of *reh* is the depth of various soils through which active evaporation can be sustained by capillary action. Mr. Ibbetson's field observations in the *reh* lands of Karnál have suggested to him about 12 feet as a maximum range for this effect; but as such observations are affected by unknown conditions of percolation, it would be of great importance to have some careful experiments made under competent supervision. I have thought how this might be accomplished, and if the Government approves of the proposal, and would sanction the small necessary expense, I would complete the scheme for execution. It would be essential to conduct these experiments in the climate of the North-West, and I should have preferred some of the drier regions of the lower Duáb; but the importance of efficient supervision is so great that I would name Roorkee as the most suitable place. I have discussed the matter with Captain Cunningham, R.E., who has kindly offered to control the observations, if made at that station.

21. I would close these brief remarks with a word of caution. Twenty years ago advice was given, *à propos* of the Western Jumna Canal, to the same purport as in the foregoing paragraphs; but it seems to have remained unheeded. The Ganges Canal was then in its infancy, and already the mischief has declared itself on a large scale. A perusal of the correspondence makes it plain where the obstruction lies: in my long experience of the question I have never known a canal officer to speak rationally on it, *i.e.*, with a knowledge of the many conditions involved in the production of *reh*. I do not mention this to attach blame to any one. A man cannot give what he has not got; and it is hard for a professional man to disown a knowledge imputed to him. The responsibility rests with higher authorities who had not intelligence to see that the *reh* question is not primarily one of engineering.

H. B. MEDLICOTT,

The 5th March, 1878.

Supdt., Geological Survey of India.

Note by DENZIL IBBETSON, ESQ., C.S., Settlement Officer, Karnál, Panjáb.

CLOSE examination of the *reh*-infected tracts on the Western Jumna Canal at Karnál, confirmed by what I have seen on the Ganges Canal at Aligarh, has led me to the following conclusions:—

That *reh* is brought to the surface of the ground by capillary action, and collected there by continual evaporation of water holding it in solution. That its distribution is wholly determined by such circumstances as affect capillary action and evaporation.

Capillary action.

The possibility or otherwise of capillary action depends upon two main conditions:—

I.—The distance of the water-table from the surface.

II.—The nature of the intervening soil.

First Note by D. J. BETSON, Esq.

The extent of capillary action, where possible, depends partly upon the two conditions just specified, and partly upon the amount of evaporation going on at the surface.

The extent to which evaporation can take place at the surface is chiefly determined by—
Evaporation.

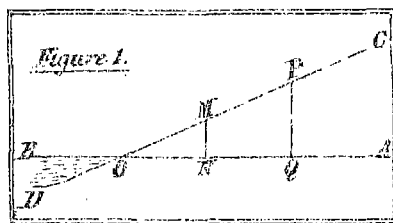
I.—The nature of the surface of the soil.

II.—The degree of protection afforded by shade.

2. Let (figure 1) A B be the water-table intersecting B C, the ground surface, at O. O B will be a jhāl. Let P Q be the greatest height through which capillarity can raise water in the particular soil in question. Then P C will be free from *reh*, because no salts in solution can reach the surface. All through P O the water will rise to the surface, and as it begins to evaporate any salts that it may contain will be concentrated in the solution. But there will be a distance M N, within which capillary action will be so profuse that evaporation cannot keep pace with it, so that water will collect to a certain extent in the surface soil; and as fast as the solution of salts is concentrated at the top, the balance will be restored by convection or diffusion downwards. In other words, there will be a distance M N, within which circulation, whether of salts, of water, or of both, will be possible both upwards and downwards. Thus in O M no collection of *reh* at the surface will be possible.

The three zones.

There will therefore be three zones :—



(a).—O M, where the water is too near the surface, and the surface too wet, for *reh* to collect: this is usually occupied by "dry swamp."

(b).—P C, where the water is too far from the surface for *reh* to be brought there by it.

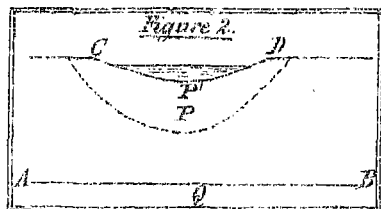
(c).—M P, the intermediate or *reh*-bearing zone.

The general connection between the water level and *reh* is shown by the fact that when, under the Mughal dynasty, the Western Jumna Canal was open, *reh* was (so say the people) common throughout the tract, though not so highly developed as now. During the century of Mahratta misrule the canal was closed, and the *reh* disappeared. The canal was re-opened in 1820, an irrigation far more extensive than had previously existed was established in 1838, and swamps and *reh* were the almost immediate result. Now the only effect of the canal upon the tract is to extend irrigation and cultivation and to raise the water level; and as irrigated and cultivated land is the last to suffer from *reh*, the action in question must be referred to the higher water-level. As to the details of the action, instances may be seen all through *reh*-affected tracts. Broadly speaking, the difference between Karnāl and Aligarh is a case in point. In Karnāl universal interference with the surface drainage, and extensive and profuse irrigation, have brought the water-table much nearer to the surface than is the case in Aligarh. Consequently the Karnāl drainage lines near the canal fall for the most part within zone O M, and are free from *reh*, while the ridges between them are all included in zone M P, and are covered with *reh*. In Aligarh, on the other hand, the drainage lines, or lowest parts of the tract, are covered with salts, because coming under zone M P, while the higher parts fall within zone P C, and are free.

3. The local capillary action may be aided by water soaking downwards from the top, as well as by raising the general water level from the bottom. If (figure 2) C D be a local depression in which water collects, then, although P'Q, the minimum distance of the water-table from

the surface, may be greater than P Q, the maximum depth of dry soil through which capillary action can take place, yet there will be a soakage from C D, bounded by the dotted blue line, which, meeting the water rising from below as high as P by capillary action, may complete the communication with the surface, and locally reproduce the three zones already described. Inundation or excessive rainfall will act in a somewhat similar manner.

First Note by D. In-
RETSON, Esq.



The effects described may be observed round any pond or jhil on the edge of the *reh* tracts. Inundated land in Aligarh suffers more severely than the drier spots close by, even where the difference in level is too small to explain the contrast observable.

In Karnál a season of unusually heavy rain extends the boundaries of the *reh*, and brings it up to the surface in spots too high to be ordinarily affected. In such spots, where it is only in occasional years that excessive rain brings the surface within the limit of capillary action, the *reh* on the surface represents the accumulation of those years only, *minus* the amount carried down again in the intermediate seasons; and is therefore less abundant than at the neighbouring lower levels, where *reh* is deposited year by year.

4. The maximum distance through which capillary action can take place must vary with the consistence of the soil. *Dakar* or *chiknot* (clayey soil) never shows *reh* (other than the mere scum left by the evaporation of surface drainage holding salts in solution), because it is too close in texture for capillary action to be possible. It is true that this soil is mostly found in drainage lines, where the *reh* deposited in one year might possibly be carried off in solution by the next floods. But this consideration cannot explain the freedom of clay soils from *reh* when they occur in local depressions, where the deposit should otherwise be specially great. So, too, *bhar*, or sandy soil, is too open for capillary action to be possible. Within my experience, *reh* never appears in sand. Throughout the tract bordering on the Jumna it shows itself in small quantities, wherever the soil is tolerably stiff, while conterminous sandy tracts at the same level are entirely free.

Facts in support.

Facts in support are given above.

5. Capillary action may be so free that the quantity of water brought to the surface depends upon the quantity evaporated there. It may, on the other hand, be so scanty that the quantity evaporated is limited by the quantity brought to the surface. But, in any case, any conditions affecting the rapidity of evaporation must also affect the rapidity with which *reh* accumulates. Those conditions I believe to consist chiefly in —

(a.)—The nature of the surface.

(b.)—The degree of protection afforded by shade.

Where the surface of the soil is broken up and kept open, as by ploughing, evaporation is enormously diminished; partly, no doubt, because the covering layer of pulverised soil acts more or less like sand in opposing an obstacle to capillary action; but still more, because it checks the absorption and radiation of heat. Colonel Corbett treats this subject fully in a pamphlet lately reviewed by Mr. Buck, and brings forward numerous facts in support of the position, if support be needed. No doubt the flocculent covering of *reh*, when it has reached a certain thickness, itself acts as a bar to further accumulation, and thus sets a limit to the concentration of the salt contained in the subsoil water upon the spots where it is being deposited.

First Note by D. In-
DEISON, Esq.

Again, any shade, whether afforded by standing crops, by trees, or by bushes, Shade a protection. must of necessity reduce evaporation.

Facts in support. The comparative immunity of cultivation from *reh*, the fact that the ground protected by the shadow of a tree in the midst of a *reh*-affected plain will be the last to suffer, and the fact that *reh* does not ordinarily appear under shrubs and bushes (noted at pages 7 and 8 of Mr. Buck's note on *reh*),* are instances in point. The partial protection afforded by shrubs is, I think, as much due to the loose layer of wind-borne dust and sand which collects at the roots, as to the actual shadow of the plant.

6. I believe the above to be a practically exhaustive enumeration of the conditions determining the distribution of *reh* in *uncultivated* land. Conditions governing the distribution and spread of *reh* in uncultivated ground. Where the soil separating the surface and the water-table is of such a depth and nature that capillary action, aided by any local soakage, can connect the two, and yet will not be too rapid to allow of surface desiccation, then in the absence of any extraordinary protection, such as may be afforded by trees, &c., *reh* must accumulate on the surface. On the other hand, where this condition is absent, I believe that *reh* will never appear in appreciable quantities.

I do not believe that *reh* is spread over uncultivated land to any material extent by wind or surface-washing. The small amount of *reh* blown in small quantities only. by the wind would be carried down into the soil by the first rain that fell. The quantity of salts carried in solution by surface drainage is not large; for the first light showers, which are for the most part absorbed where they fall, carry the salt under the surface, as pointed out by Mr. Buck, and thus, by a kind of occlusion, preserve it from removal. The water of jhils and ponds in the worst *reh* tracts is almost always sweet; and the slight film of salt left by the evaporation of surface water is very distinct from the flocculent deposit collected from below.

Mr. Buck's theory of *reh*-traps (see pages 5 and 6 of his note) appears to me untenable, so far as uncultivated land is concerned; for, even if surface drainage had a greater tendency than I believe it to have to collect the *reh* into hollows (see Mr. Buck's pictures on page 5), still diffusion in the subsoil water would, in the absence of underground partitions, infallibly equalise the distribution as fast as it was disturbed. As a fact, in the Karnál canal tract, the low-lying spots are the freest from *reh*.

In any case, a *terminus a quo* is no less necessary than a *terminus ad quem*; and if *reh* be found both at A and B, before we can believe that it has been transferred from A to B, we must have some reason to think that the same causes which determined its existence at A are not sufficient of themselves to account for its presence at B. Reh not spread by surface transfer.

Facts in support. Instances are too universal to be given in detail. I hope shortly to submit sections of the Karnál district, showing water levels and surface soils, which will speak more plainly and be more trustworthy than any verbal description.

7. Land under cultivation, being protected by the more open surface of the soil, and by the shadow of the crops, is the last to be affected by *reh*; and though some evaporation must take place, and therefore some salt be deposited at the surface, yet the deposit of one year is worked into the soil by the ploughings of the next, instead of being allowed to accumulate at the surface. The plants no doubt absorb a certain portion of the salts; while chemical action, promoted by the exposure of the subsoil, and often aided by manure, probably helps to keep them in check. Thus the accumulation of *reh* at

* A note published with Board of Revenue's report on *reh* to Government in 1874, No 231N, dated 21st October.

the surface of cultivated land *in general* is an infinitely slower process than that which takes place in uncultivated ground; though the process, however slow, is probably continuous.

First Note by D. IR-
BETSON, Esq.

But since *reh*-bearing water exists no less under cultivated than under uncultivated land, and since the comparative immunity of the former is almost entirely due to its being protected against evaporation, *any* local causes that may tend to diminish this protection, must, *pro tanto*, tend to accelerate the deposit of *reh* in the affected spots. The nature and action of these causes are admirably discussed by Mr. Buck in his note. The *reh* is blown on to the cultivation by the wind, is washed over the edges of the outlying fields, or is carried on to them by surface drainage or irrigation water which has passed over *reh*-encrusted plains and deposited at the lowest points of the fields.

The amount of salt so deposited is, I believe, of itself quite inadequate to render the soil absolutely barren, or to account for the thick efflorescence to be found in such places. On the deep saline wells of the upper Panjáb, where the water judging from the taste, contains many times more salt than does the drainage water here, it takes five or six years' continuous irrigation to deposit *reh* to an injurious extent; and even then, two or three seasons of fallow suffice to wash the salts down again, and to free the surface from them entirely. But the salt so deposited by wind or water is sufficient to temporarily check or destroy vegetable growth on the affected spots, and so to turn the scale, and locally determine the contest in favour of *reh*. And when a *reh* spot is once thus established in a field, it acts as a centre of action from which the evil spreads in the manner just described. In short, I believe that the *direct* action of *reh* washed or blown on to fields is quite insignificant compared with its *indirect* action in diminishing or destroying the external protection which alone keeps the underground salts from collecting on the surface of the soil. Suppose we took a hundred-acre block of cultivation, lying in the midst of a *reh* plain, with uniform level and water-table, and as yet unaffected by *reh*. I believe that, if cultivation were discontinued in the two central fields of that block, *reh* would accumulate in them from below far more quickly than it would be deposited by wind and water on the outlying fields which border on the *reh* plain. And I believe that if one of these two fields were yearly ploughed up, but not sown, the action in it would be slower than in the one left untouched, but still more rapid than in any one of the cultivated fields.

Did space permit, it would be easy to add largely to the detailed instances which Mr. Buck has given. All I can do here is to say generally that, throughout Karnál at least, the weaker the cultivation, the more rapid is the spread of *reh*. Outlying fields, levels being the same, always suffer first; while a year's fallow is usually fatal. A Ját village, with plenty of manure and careful cultivation, will produce fine crops year by year within a few inches of a sheet of *reh*; while in a contiguous and similarly situated Gújar village the *reh* will steadily encroach in every direction upon the cultivation.

8. If the foregoing account of the causes governing the distribution of *reh* be correct, it is clear that the *immediate* source of *reh* is, at present, the subsoil water. That it is not deposited *in situ* by irrigation is obvious from the fact that, for every square inch of *reh* soil in irrigated (and therefore cultivated) ground, there will be in a *reh* tract an acre of far more excessive deposit on uncultivated (and therefore unirrigated) soil. Now the subsoil water may have received the salts from the canal water, or from the soil itself, or from both. My opinion would be valueless as to the relative degree in which each of these joint factors contributes to the result; but the following suggestions may be worthy of consideration.

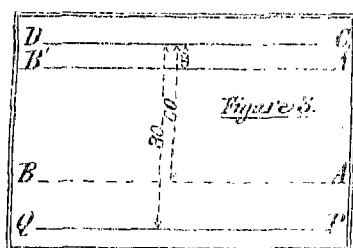
First Note by D. In-
RETSON, Esq.

I take the very worst bit of the worst *reh* tract in India, viz., the upper part of the Duáb between the Delhi and Rohtak branches of the Western Jumna Canal. It has a total area of—

52,057 acres, of which	{	22,889 acres are cultivated,
		21,577 „ are irrigated from the canal,
		3,473 „ are under water,
		18,138 „ are <i>reh</i> plains.

The duty of canal water shows that, *not allowing anything* for evaporation on the road from the canal heads, the irrigation only amounts to 62 inches on the irrigated area, equivalent to 26 inches over the whole tract. Mr. Medlicott's analyses (Selections from Government of India Records, No. XLII., Public Works Department) show that the canal water contains 23 parts by weight, or say 16 by bulk, in a million of *reh*-forming salts. At this rate it would take 2,405 years of unintermitted irrigation to add to the subsoil water the constituents of one inch of *reh* over the whole area, and 842 years if the inch of *reh* is taken over the existing *reh* plains only.

As to the amount of salts derived from the subsoil itself, I must refer to figure 3. Let C D be the surface of the ground; P Q the pan separating the soakage waters from the spring waters; A B the old water-table before the canal was re-opened; A' B' the present water-table. The distances in feet given in the picture are the actual figures for the Duáb just mentioned. Now the action of rain for successive ages before the coming of the canal will have washed the greater part of the saline constituents of the whole 80 feet of soil into the water contained in the 20 feet between A B and P Q, and the water will have been bitter, as in most deep wells in the neighbourhood. The raising of the water level will have diluted this water with $2\frac{1}{2}$ times its bulk; but still the whole of the salts will be held in solution in the water



included in the 70 feet between A B and P Q. Now supposing that the soil *originally* contained only one per cent. of *reh*-forming salts (a perfectly harmless proportion), the evaporation of the water contained in 8 feet of the water-bearing stratum would furnish the constituents of one inch of *reh* over the whole tract, while if we confine the *reh* to the existing *reh* plains, the 8 feet are reduced to $2\frac{1}{2}$ feet. The analyses of subsoils made by Mr. Medlicott (page 36 of Selections) do not, I think, give the *original* constitution of the soil, but represent only such salts as are left in it *after* the washing and diluting process above described;

and those particular soils were taken from the most swampy villages in the Duáb, where percolation from the canal is profuse, and the well water quite sweet in consequence, and from a neighbourhood when much of the salts has already been collected on the surface in the form of *reh*. In fact, no analysis of subsoil can show how much salt that subsoil may have contributed to the waters *previously* to the analysis.

Again, if *reh* is chiefly derived from the canal water rather than from the soil, well water should not grow, as it does, more and more bitter as you go further into the Duáb, and away from the canal, till in the centre, almost out of the *reh* range, it is nearly undrinkable.

Again, the composition of *reh*, judging from the industrial uses to which it can be put, would seem to vary considerably, not only on different canals, but in separate localities on the same canal. This should not be the case if it is chiefly derived from the canal water, as the composition of the water is practically constant.

Finally, *reh* is found over large areas miles away from any canal or canal irrigation, past or present. First Note by D. L. BETSON, Esq.

9. I hold therefore that a high-water level is the immediate cause of *reh*; and I believe that the only way of attacking the evil at its root is to keep the water-table below the maximum depth from which *reh* can be raised by capillary action to the surface. Other measures may have a local or temporary value, but they are at best but trifling and tinkering. It is but little use excising the cancer if the poison remain in the blood.

The high-water level is produced by three causes: percolation of water from the canal and its distributaries; interference with the natural surface drainage; and canal irrigation.

That percolation from the canal does take place to a considerable extent, I know from having seen when the canal has begun to flow again after having been temporarily dry, the percolation water flowing out of one field into another as if from a well channel; and that in stiff soil, and at a distance of 300 or 400 yards from the canal. But where the canal is well in soil, as at Aligarh, I doubt whether the percolation can be great; and where the alignment is good, nothing further can be done to stop the percolation (unless puddling be feasible) for to carry the water along the lowest levels instead of on the ridges (as has been suggested) must inevitably result in the silting up and stoppage of drainages, an effect which is probably far more harmful than percolation.

Where, as in Karnál, every drainage line in the country is crossed at intervals by high banks, the stoppage of the natural channels by which the surface water should be carried off aids most materially in water-logging the country. But this evil can always be met by proper alignment of the channels, and by scrupulously keeping the drainage lines open under the Canal Act. The drainages should of course be cleared *from the bottom*, and not from the upper end, as has been done in several instances, to the great injury of the people.

But I believe the *chief* cause of the high-water level is to be found in the nature and extent of the canal irrigation practised; and I lay more stress than ever on this cause, since I have seen that the perfect alignment of the Ganges Canal has not availed to save the neighbouring tract from water-logging.

If 50 gallons are lifted from a well and poured on to a field, and if 20 of them evaporate and 30 sink down again, there will be 20 gallons less water below the surface than before the operation. But if 50 gallons of canal water take the place of the well water, there will be 30 gallons *more* water in the subsoil than there were before. Thus canal irrigation, however limited, must in the end raise the water-level. But when we add to this the fact that canal water, when obtained by flow, is used with such utter recklessness that a quantity equivalent to 62 inches a year is put on to the fields; that a well, working under average conditions, would have to deliver over 6,000 gallons an hour in order to afford a similar supply to the fields it irrigates, whereas 1,200 gallons is probably an extravagant estimate of its actual delivery; and that in very many villages *every cultivated acre* is irrigated in this manner once, and much of it twice in the year,—an idea may be formed of the amount of water yearly poured on to the country. In the tract for which I have given the figures the canal irrigation is equal to a rainfall of more than 27 inches *over the whole area*. Add to this 25 inches of natural rainfall, check evaporation by extended cultivation, stop the drainages, and what wonder that the water-table rises.

10. How, then, is this lavish use of water to be checked? No practicable method of charging for water by volume has yet been discovered.

First Note by D. In-
NERTSON, Esq.

To diminish the water-supply, or to limit the area yearly irrigated in any village, is practically to deny water altogether to the poorer and weaker members of the community; while it is only on new canals that it can be done at all; for where canal irrigation is of long-standing, it has profoundly modified the whole agricultural economy of the villages.

It has been proposed to give canal officers plenary powers over the details of irrigation. I think the scheme open to somewhat the same objections as might be urged against a proposal to put the drainage details into the hands of the civil staff; and generally I think that the more we can abstain from meddling with details the better; for the people alone have the minute knowledge necessary to make such interference successful.

To charge higher rates for fields irrigated as a whole instead of by *kiáris* (small beds which economise the water by acting as terraces, and by preventing it from traversing already saturated soil) will do much towards saving water, though it will increase the opportunities of the canal *chaukidar*, already known as *naib-khuda*, or deputy god, on the Western Jumna Canal.

To charge higher rates for the second, and prohibitive rates for the third consecutive season in which the same field may be watered, will not only restrict the irrigated area without causing inequality, but will also give the fields the rest so generally denied them in canal villages. These last two measures I most strongly recommend, in the absence of more radical remedies.

In swampy parts, such as we have in many of the Karnál villages, wells, if they can be made at all, should be built either at Government expense, or aided by Government loans, and the people referred to them for their water. Irrigation from them, where water is within three feet of the surface, entails the minimum of labour, while it keeps down the subsoil water instead of increasing it. But the people say, and the state of existing wells seems to support the statement, that wells cannot be made in swampy soil, and do not last where *reh* is present in quantity, the bricks crumbling away under its influence.

11. But all these remedies are but child's play in view of the magnitude of the evil. Long consideration has forced me most unwillingly to conclude that there is *no* remedy worthy of the name, short of making the people lift every *drop* of water they use. Water would be distributed, as at present, at a high level; but having brought it to the field, I would deliver it into a small reservoir, and make the irrigator raise it again by the labour either of men or of bullocks. Such apparently wanton waste of power is of course revolting to the very soul of an engineer. It is, as a canal officer put it, like returning from breech to muzzle-loaders. But if I had a boy who could not be trusted with a breech-loader, I should certainly prefer his using a muzzle-loader to the certainty of his shooting himself. Children and fools must be treated as such. So long as a native can, by a stroke of his spade, obtain as much water as he chooses to take, and can put 10 inches of water on his field at the same cost in money as, and at less cost of labour than, if he had put five inches only, so long is economy in the use of that water *out of the question*. Even in a famine year like the present water is running to waste all over the country; the lower end of a field is put under seven inches of water in order to get one inch on the upper end, and the most reckless profusion is universal. But where the water is lifted by a scoop or otherwise, the fields are terraced, the channels are kept in good order, and the severest economy is everywhere practised. With the natives of these parts *dál ká simána*, or an area irrigated by lift, is proverbially synonymous with a prosperous village.

Nor is the saving of water which it would force upon the villagers the only advantage that would result from this system. It would entirely do away with the necessity of the half-yearly canal measurements, and so save, not only their cost, but also the attendant annoyance to the

people. It would also render impossible nine-tenths of that extortion which the minor canal subordinates, like the subordinates of every other department when opportunity offers, do undoubtedly practise to a great extent. The amount of water that can be raised, and the area that can be irrigated from a single scoop, wheel, or bucket, is practically constant; and it would be easy to substitute for the present elaborate system of area measurement and differential crop rates a fixed charge for each scoop, wheel, or bucket to which water had been supplied. The only supervision that would then be necessary would be directed to taking care that no water was surreptitiously raised by unauthorised means.

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The more I reflect on the problem, the more I am convinced that this is the only way in which water can safely be placed at the disposal of people so ignorant and so improvident as those we have to deal with. The change would, I believe, save *fully* half the water used, the surplus becoming available for extending irrigation to distant villages. And it would assimilate, in some measure, the conditions of canal to those of well irrigation; fields would get rest occasionally, and that ruinous overcropping of unmanured over irrigated land, which is now so general, would be put a stop to to a very great extent.

At present the villager positively saves himself a good deal of labour by using water wastefully; I would substitute a system under which he could save himself labour only by economising water.

12. I attach great importance to keeping the natural drainage lines of the country open. No dams or cultivation should be allowed in them. The more water we can induce to flow away from the canal tracts the better; while any *reh* that it may carry with it in solution is so far a gain. Local accumulations of water, moreover, are directly injurious, as pointed out in section 3. Subsoil drainage is of course prohibited by the expense and absence of fall, or it would probably be far more efficacious than mere surface drainage, as it would carry off water which had passed through the most strongly impregnated portion of the soil, and which would therefore have a considerable quantity of the salts in solution.

Planting trees, where *reh* is not so far advanced as to kill them in their early growth, would, I believe, exercise a most valuable influence, the shade acting, as already explained, as a protection against *reh*. I should say they could not be placed better than between the *reh* plains and the cultivation, so as to interpose between the two a shade-protected belt of ground, and protect the fields from the washings, which are, whether directly or indirectly, most harmful.

Collecting and removing *reh* from the surface seems an almost hopeless task. I have already pointed out in section 5 that the store of salts below would never be entirely accumulated on the surface, and if the calculation in section 8 be correct, there is enough salt in the 70 feet of subsoil water to furnish a depth of nine inches of pure *reh* over the whole area.

Relief, in the form of remission of assessment, where that relief can be extended to the actual *cultivators* of injured villages, should be prompt and ample; for, as stated at the end of section 7, the people need all their strength to fight the enemy with any hope of success, and Karnál experience distinctly shows that to grant relief grudgingly in the beginning, only entails far heavier loss upon Government in the end.

13. I would, then, substitute lift for flow irrigation throughout, and a fixed charge per scoop, bucket, or wheel for crop rates per acre. In swampy localities I would substitute wells for the canal. In default of these measures, I would charge higher for fields without than for fields with *kiáris*; and I would take enhanced rates for a second

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year's watering, and still higher ones for a third year's consecutive irrigation of the same field. I would clear out the drainage lines from the bottom, and declare them under the Canal Act. I would also plant trees, especially between the cultivation and the *reh* plains. Finally, I would unhesitatingly give ample relief, in the form of remission of demand, to injured villages, so long as that relief could be extended to the individual cultivators.

14. I have written throughout *en cathedrâ infallibili* because, even without deprecatory remarks, I have failed to arrive at brevity. But
Concluding remarks.

I am fully aware that, on many of the points which I have touched, an unscientific opinion is of but little value. Still it was necessary to make my argument continuous, in order to make it intelligible. Moreover, I have been engaged for nearly six years in minute field-to-field examination of the worst *reh* tract in India, and the impression made by the actual facts upon an intelligent, though uninstructed, observer has always a certain value of its own.

I had much hoped to send with this memorandum some sections of the canal tract in this district, for I believe that they would have afforded valuable evidence on some of the points in question. Especially, I believe that they would throw some light on the degree of percolation which takes place from the canal; and also upon what is practically the most important datum in the enquiry, *viz.*, the distance which must intervene between the surface and the water-table, in order to render the former safe from *reh*. Roughly speaking, I should say it was about 15 feet, though such a guess is worth but little.

But my mapper does not understand sections, and I have been far too busy since my return from Aligarh to attempt to make them myself. But when I return from leave, about a month hence, I hope to be able to prepare some, and that they will not be too late to be of use to the sub-committee.

D. IBBETSON,

Settlement Officer, Karnâl, Panjâb.

Note by E. C. BUCK, Esq., *Director of Agriculture and Commerce,*
N.-W. P. and Oudh.

I HAVE been desired by the president to place on record my opinion on the general questions discussed by the committee. I have had myself a long experience in districts affected by *reh*, having for some years made a close examination of the features of its surface distribution, and the opportunity has now been given to me of gaining, through the knowledge and experience of others, a deeper insight into the method of its movements under the soil. In the following note I sometimes express the opinion and even the words of other members of the committee; but so far as I desire to adopt them as my own, I conceive that I am carrying out the wishes of the president in placing them on record.

2. *Reh* has been scientifically described as denoting highly soluble salts, the presence of which is common in many soils. There are three elements necessary to the collection of *reh* at the surface of the earth:—

- (1) A strong evaporating force.
- (2) Water within reach of that force.
- (3) *Reh* with which that water can come into contact.

Water seizes upon, binds in solution, and when drawn upwards by the irresistible force of the sun, drags with it to the surface every particle of *reh* which comes within its grasp; and until the very last moment, when it is itself dissolved into vapour under the compulsion of the stronger force, refuses to loose its hold upon the tightly bound captive. Under the influence of long and continuous evaporating action fresh accessions of salt are thus brought continually to the surface; and the fact that the most extensive outcrops of *reh* occur chiefly on the scorched plains of North India, is due probably to the circumstance that evaporation acts more freely in a dry atmosphere through which radiation can pass unimpeded by vapour.

3. It is evident therefore that if there is any section of the earth's crust below the surface of which there is a supply of *reh* and of water, and which is also subject to the action of continuous or protracted evaporating force, there is no limit to the amount of *reh* which may be collected on the surface of that section : provided—

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- (1) That water, which is or can become infected by *reh* lies within reach of the evaporating force,
- (2) That none of the *reh* brought to the surface is liable to removal after being brought there.

It is the question which is connected with (1), *viz.*, the distribution of *reh* and water under the surface, which is the primary and most important subject for consideration.

That which is connected with (2), *viz.*, the distribution of *reh* over the surface is a secondary question.

4. The discussion of the primary proposition in paragraph 3 involves questions relating to the distribution of *reh* and *reh*-bearing water below the surface, of which the treatment by unscientific men is not unlikely to mislead, and the investigation of which must be left to scientific geologists. I believe, however, that I am safe in assuming that competent authorities admit that underground accumulations of water are collected in the hollows or depressions of strata of stiff soil, and that such accumulations are sometimes fed from a salt-polluted source.

5. It appears proved by facts, to which I will recur when dealing with the influence of canals upon *reh* production, that a rise in the level of the main body of water underlying the surface is frequently accompanied by a greater development of *reh* at the surface, and often in new places. It seems possible to ascribe these results as well to an increase in the evaporating process due to the approach of the main body of water to the surface, as to a change in the geographical distribution of underground accumulations, which with every change in level may find new centres of rest.

6. It is that water which underlies a salt-infected soil, or which has already collected from salt-infected soil a quantity of *reh* in solution, which brought to the surface by evaporating force destroys vegetation. But even where there is such water, *i.e.*, either infected, or liable in its passage to the surface to infection, its free movement upwards may be interrupted, either wholly or partly, by strata, or patches of impermeable soil. While therefore we have already an irregularity in the distribution of *reh*, owing to irregularity in the position of accumulating areas of water below the surface, we have yet another cause of irregularity in the varying density of soils which lie between the accumulating areas and the surface.

7. The next question to be considered—one to which I cannot but think that too little importance is attributed—is the later history of *reh* after it has been deposited on the surface of the earth. No longer subject to the evaporating force, it lies inactive on the ground, until again it becomes a helpless victim to its first captor, water, which this time descending upon it in the form of rain, seizes it as promptly as before, and obedient itself to the forces of gravity and absorption, carries it off wherever entrance can most easily be found. Here the important fact must be appreciated that it is only that rain which falls after a period of evaporation which has the opportunity of finding on the ground *reh* which it can dissolve and carry off. It is plain therefore that the history of that, the earlier rain must be studied and followed before the circumstances of surface distribution can be fully understood. If it is admitted that, as a rule, after a protracted period of evaporation over a *reh*-infected section of the earth's crust there is an enormously larger percentage of *reh* on the surface than at any one given depth below, then the deduction seems incontrovertible, that the first falling rain has at its mercy, and subject to its control, a very much larger amount of *reh* than any other equal volume of water below the surface.

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8. We must therefore find out what becomes of that early rainfall which has the opportunity of taking up *reh* in solution. It may follow three courses :—

- (1) sink into the ground, and be at once absorbed ;
- (2) sink through the upper strata of soil to the main body of water below ;
- (3) be washed horizontally over the surface.

9. It is conceivable that if the first action occurs, and rain water can escape vertically downwards through the upper strata, and escape by natural drainage underground to the main body of purer water, *reh* may be removed as fast as it accumulates ; if, however, the second action occurs, and the *reh*-polluted water of the first rainfall is caught in those upper strata which are difficult of permeation, then the *reh* is merely hidden below the surface, locked up as it were in a box, until evaporation recurring opens the lid and sets it free. And this may be the case (as I have witnessed in more than one instance), notwithstanding the fact that a free flow of water to some depth washes over the very same section of land into deep drainage lines. The deeper water, being the result of later rainfalls, is clean and pure of *reh*, with which, locked as it is in the ground below, these later rains cannot come into contact.

10. Some pollution, however, is undoubtedly contracted by that portion of the earlier rainfall which does not sink immediately into the ground, but spreads over surrounding land, or finds its way along drainage lines ; and many cases were brought to the notice of the committee, which gave clear evidence of *reh* having been washed over the surface from one area to another. It is true that the distribution of *reh* after it has once been brought to the surface may properly be described as a secondary process, the primary one being that by which it is brought from below. But is it not as necessary to effect a diagnosis, and, if possible, a cure of the disease itself, as to deal with the causes which give rise to it ? Would a doctor be forgiven for refusing to give a draught to a cholera patient on the ground that it is better to ascertain and remove the causes which brought cholera to the locality in which he lived ! I do not say that the first and strongest efforts should not be directed against originating forces, just as the most powerful opposition is brought against cholera by the removal of unsanitary conditions. But it is not yet certain that either engineer or physician can practically effect reform on such a scale as will ensure the prevention of the primary evils which they wish to overcome. An over-supply of canal water is no doubt the cause of fresh outbreaks of defertilization, just as an unwieldy concourse of people is the foundation of a new epidemic. But is it not as unlikely that the canal lock-gates will be permanently closed at Hardwár, as that police sentries will prevent pilgrims from approaching that same holy but cholera-spreading centre at the time of the annual fair ?

11. I may also bring to notice another secondary action in the distribution of *reh* which is very forcibly impressed upon those whom unkindly fate at any time obliges—as it has often obliged me—to traverse in the hottest months of the year—a *reh*-covered plain within the neighbourhood of a canal system with its raised water level. Ground, of which until the canal came near it no inconsiderable areas were covered with a stunted grass, is now no less hoary than a frost-stricken plain in the Arctic regions ; for *reh*, thick as driven snow, lies concentrated upon the surface at the mercy, not only of water, but also of air, which, when the fierce and scorching west winds scour the plains, is lifted in thick clouds into the atmosphere, and rolled in whirling columns over the adjacent country. I am convinced that the action of the canal in raising the water level, and thus bringing to the surface of old *reh* plains an enormous accession of efflorescent salts, and placing them at the disposal of the strong winds of the hot weather, has assisted much in the dispersion of *reh*, which will, as time goes on, defertilize the land over which year after year it is being swept. The agency which I have thus described is purely of a subordinate character, but its power of doing mischief has been greatly increased by the supply of *reh*, with which it has been fed by the primary action of canal water in concentrating *reh* on the surface.

12. As a most important instance (because occurring on a large geographical scale) of surface removal of *reh*, the case of the deposit at the mouth of the river Nūn in the Cawnpore district demands attention. The river takes its rise in a surface catch-basin, on which numerous depressions of more or less impermeable soil occur, and a large number of which are more or less affected by *reh*. When the rains first commence the water of the river is said for two or three days to assume the deep reddish-brown appearance, which is the peculiar indication of water strongly impregnated by *reh*. In dry weather the narrow bed of the Nūn itself and the delta at its mouth are found full of *reh*, so full that some villages through which it runs make an income from the sale of it. It must be noted that although the river-bed and the delta are thus infected, yet that the country on either side of the river-bed is quite pure of *reh*, after the river has once fairly left the *reh*-polluted basin. The alluvial delta at the mouth is so strongly impregnated, that a considerable area is always unculturable; and when canal irrigation was lately introduced into a small section of it, the increased evaporating action gave rise to such a startling addition to the unculturable areas of land, that the revenue authorities interfered, and objected to the continuance of canal irrigation. It should also be noted that no alluvial deposit of the Ganges itself within the same or adjacent districts is affected by *reh* in the same manner, from which circumstance the assumption must be deduced that the *reh* is due, not to the water of the Ganges, but to that of the Nūn. A map of the catch-basin of the river Nūn, in which I indicated in detail the surface distribution of *reh* by colours, was published in 1874 by the Board of Revenue, North-Western Provinces, and I now add a map of the delta of the Nūn showing the connection between the two. The distance between the mouth of the river and the *reh*-infected catch-basin is from 10 to 15 miles, over which distance the circumstances of the case indicate that *reh* is washed from one to the other. They appear at any rate so strongly to point to this conclusion, that it would be necessary to make a close enquiry before a contrary opinion could be justified. It may be that some of the *reh*-polluted water of the catch-basin, which forms the source of the river, finds its way through subsoil strata; but it is a fact that the greatest pollution occurs in the first day or two of the rains, the presumption will be that the earlier rain brings it over the surface.

13. I believe I am quoting Mr. Medlicott when I assume that an almost permanent condition of *reh* distribution had been reached in the north of India, that *reh* had been carried under the influence of forces above described from positions of unstable equilibrium to positions of stable equilibrium, and that the geographical position of *reh* had become, if not fixed, yet subject only to very slow changes. Suddenly a canal system is introduced over the face of the country, the underground water level is disturbed, the relative positions of *reh* and water are changed, equilibrium is upset; and a fresh activity sets in. The supply of a large body of water, brought within close proximity to the surface, adds fuel to the evaporating machinery, which is thus enabled to raise larger as well as more extensive outcrops of the devastating substance.

14. Three instances of destruction on a large scale have been brought before the committee: one in the Karnāl district, of which an account will be given by Mr. Ibbetson; the second in the Aligarh district (that which was the immediate cause of the present meeting); a third in the Meerut district, which Mr. Michel, a well-known planter, has brought to prominent notice in his memorandum. A fourth case, though not brought before the committee, is well known to some of the members. I refer to the destruction of the Kālī nadi valley, which I have lately inspected. In every one of these cases the destruction of some hundreds of acres has occurred, and in every case is at once attributable to the disturbance caused by the canal in the former conditions of drainage.

15. The cases above noted, and similar cases which exist elsewhere, are the first and earliest outcome of the introduction of a canal system; and their prominence is due to the exaggeration of disturbing influences which may perhaps be working

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in a slower but not less sure action in many areas, where symptoms are still obscure or unobserved by educated eyes, just as the unsanitary condition of a locality is marked first by the disease and death of the weakest of the community, then by the gradual decline of the physical condition of the healthier members. This is a somewhat appalling prospect. But that it is not an impossible one is confirmed by the circumstance that crops appear to be deteriorating in canal irrigated land, in which although *reh* is known to exist, yet vegetation has not been absolutely destroyed. It is also certain that much mischief is occurring which has not yet been brought to notice by native landholders, who do not complain until the last moment. In the present case, for instance, nothing was known of *reh* spreading in the Aligarh district until a European zemindar sent up a petition to Government; and until Mr. Michel brought to notice the devastation which is creeping into his own and neighbouring estates, the Meerut district was supposed to be "comparatively free from *reh*," and was so reported by the Collector at no earlier a date than 1873.

16. In the Karnál, Meerut, and Aligarh instances the water level has been rapidly raised and increased evaporation caused, and in all three *reh* appears to have been produced with the greatest rapidity on the edge of saturated areas; in other words, at those points where excessive saturation below is overcome by excessive desiccation above. This fact is significant and leads to the following proposition.

Reh areas may be divided into three classes :—

- (1). Those of excessive saturation in which *reh* remains diluted and diffused, and therefore comparatively harmless.
- (2). Those of great saturation, but not so great that it cannot be overcome by great desiccation. Here the evaporating process is most active and *reh* efflorescence most marked.
- (3). Areas of small saturation, in which extreme desiccation does produce efflorescence, but at a slower rate. The drying force is equally powerful, but the carrying agent is deficient.

These areas, in which although saturation is not excessive, yet sufficient moisture exists to allow all available salts to be evaporated to the surface, are, I fear, very large, and if my apprehension is well founded, large tracts of country are doomed to destruction.

17. In the Káli nadi case the whole of the affected land is in the river-bed, within which every acre for miles is destroyed. Either canal water has brought fresh *reh* into the soil, or has brought previously occult *reh* to the surface by increasing the process of evaporation; the latter is probably the case. This destruction in the Káli nadi has been sometimes attributed merely to swamping, but in that part of the valley which I inspected near Bulandshahr I proved to my own satisfaction that it was due to *reh*, and it is curious to learn that along the edge of the broad belt of valley land which was formerly covered with crops after inundation-water had cleared off, there always existed a narrow fringe of barren *reh*-infected soil which is still much worse in appearance, and more barren of grass than the centre belt. I presume that *reh* was never washed from it.

18. I have noticed that while the primary causes of increased outcrops of *reh* are connected with changes in the distribution of water below the surface, yet that much secondary mischief is caused by water-logging and interference with drainage, which prevents the escape of *reh*-infected water. In both cases drainage is recommended as an antidote. But drainage is a wide term—I might perhaps say a deep one,—and I doubt if sufficient consideration has been given to the character of the drainage which is required. Wherever the outcrop of *reh* is due to the existence of tainted water in some stratum below the surface, that water must be tapped, or no influence will be exerted upon the mischievous cause; and, again, wherever there

is an accumulation of *reh* on the surface which it is desired to remove, the drainage system must be accessible to the very shallow surface drainage of the very earliest rainfall. But drains are often dug which lie above the former, and are protected (often by their own banks) from the latter, and consequently affect neither the action of the moving spring below, nor the injury which has accrued to the surface above.

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19. There is room to fear, however, that in many cases a complete remedy consists either in an almost impossible system of very deep drainage, or in the stoppage of the canal; for I doubt if by lowering the canal a few feet the evaporating process would be sufficiently curtailed. But if I am wrong I certainly advocate the construction of canals below, and not above the surface. It is absolutely necessary, for other reasons. To do everything possible to put an end to the present vicious system of swamping fields for irrigation purposes, which is the result of the accessibility of flush water. No check is so certain as that of making every cultivator lift his own irrigating water. The case with which the agricultural population of canal irrigated tracts can now pour an injurious amount of water on their land is leading not only to the deterioration of the soil, but also to their own demoralization (a fact of very serious import). I am far from being alone in my opinion. I can quote indigo planters, even those whose fortunes have been made by the canal. I can quote canal officers. I can quote native agriculturists. I can quote settlement officers. If therefore canals at a lower level are likely to prevent *reh* from spreading, than by all means, in the interests of agriculture, let them be so made. One of the committee objected to a return from breech-loaders to muzzle-loaders; but did he not forget that when the muzzle-loading cannon were proved to be more effective than their breech-loading rivals, the latter were justly rejected?

20. I am strongly of opinion that, with the exception of draining such areas as are manifestly swamped by interference with surface drainage, and in which injury is due to this immediately local cause, no treatment of the growing disease should be undertaken until its diagnosis has been more thoroughly effected. I have suggested to the committee the feasibility of preparing for the provinces a *reh* map similar to that which I have had prepared, and which has been placed before the committee lately under inspection; and I am ready to undertake the construction of a map of the same kind for the whole provinces, for the preparation of which a shorter or longer term will be necessary, according to the accuracy required, or according to the staff which may be allowed.

As the greater part of the work would be effected by the existing machinery of the subordinates in the record department, whose field work is under my supervision, the expense need not be great. The map once formed the progress of *reh* in every part of the provinces would be brought to light each year.

21. Mr. Medlicott has desired, I believe, that a map of the well depth in every section of the provinces shall be drawn up; and I am certainly of opinion that no sound comprehension of the conditions of underground water action can be expected until a more thorough knowledge has been obtained of water distribution under the surface. A programme for the preparation of both this map and that suggested in the last paragraph will, with the permission of the president, be brought forward by the sub-committee.

22. If *reh* land is to be cured by any system of subsoil or deep drainage, the fact, to which Mr. Medlicott has called attention, must not be forgotten, that all attempts to get rid of the salts on the surface will fail unless free communication is opened between the surface and subsoil water currents. The argument applies with the greatest force to cultivated lands, in the upper layer of which *reh* is gradually concentrating, and here deep ploughing may in some cases be found a possible alleviation.

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It shall at least be tried. The more rain water is allowed to descend vertically into the soil, the more chance there is of *reh* being washed with it into the main body of water below, where, if not carried off, it is at least diluted. The difference between the action of rain water falling from above and canal water rising from below may here be noted. Every time that canal water is evaporated to the surface of land it is liable to being salt with it, and thus add to the store in the upper layer of soil; while every time that rain falls, it carries the surface *reh* down with it, and brings, when returning to the surface by evaporation, no more to the top than it took down. Rain water carries *reh* both backwards and forwards; canal water only in one direction, and that, unfortunately, the wrong one.

23. In the last paragraph I have contrasted the action of rain water with the action of that canal water which is brought from under the surface by percolation through the soils. I shall now refer to that canal water which is brought over the surface by irrigation. There are two ways in which it can add to the deposit of *reh* on cultivated land:—

Firstly, by being brought over soil on which *reh* is deposited.

This, I regret to state, is constantly being done. Along a plain covered with salt channels are furrowed which conduct irrigation water to adjacent fields which collect at their surface efflorescing salts. Every time that water flows through them it drinks up the salts lying in their bed, and carries most of the poison it collects into the irrigated field. At the same time the fresh saturation which the channel receives provides it with a renewed power to draw up from the subsoil a new supply of salt, with which to pollute the next stream of water, which after a short period will be brought into the cultivated land.

Secondly, canal water adds to *reh* deposit by bringing with it a fresh supply of *reh* from the canal itself. The quantity of *reh* which water in the canal contains appears to be very minute, but it is said by analysis to be perceptible, and if so, must be constantly adding to the surface stock. As a rule, every drop of canal water is either taken up by the crop which it irrigates or is evaporated into the atmosphere, and in either case it must leave on the surface all salt which may not be absorbed by the crop. If any surplus does remain on the ground, than only time is required to render every acre of canal irrigated land unculturable. Analysis, which points out the danger, may perhaps be able to give actual proof of the facts which it indicates by a scientific examination of the soil of adjacent fields irrigated for a series of years in one case by well water, and in the other by canal water. The future which is foreshadowed by the hypothesis is alarming, and not least so to those who have seen the extensive areas of land in the Upper Provinces which are at this moment laid waste by *reh*. A glance at the map of a portion of the Cawnpore district to which I have previously alluded illustrates the power of its mischievous action in the very large area which bears the colour denoting sterility.

24. In conclusion, I am of opinion that the following propositions should be made the basis of proposals for any curative or preventive action to be taken under the orders of Government:—

- (1.) Certain conditions in the subsoil strata are followed by the development of *reh* at the surface. These are the primary causes of *reh* distribution.
- (2.) When *reh* has been brought to the surface, it is or may be distributed by causes acting in or near the surface. These are the secondary causes of *reh* distribution.
- (3.) Primary conditions are not fully understood, and their geological geography is very incompletely ascertained.
- (4.) It is necessary to take measures to ascertain (3), in order to discover how far primary causes can be efficiently opposed or removed.

- (5.) It is necessary to investigate secondary conditions in order to ascertain how far to alleviate the disease in all cases where primary action cannot be prevented.
- (6.) So far as primary or secondary causes are understood or supposed to be understood, experiments should be made with a view to testing the value of any remedy which may be proposed for their removal.

Notes by CAPTAIN
T. HOWARD, R.E.,
and R. E. FOR-
REST, Esq.

25. I have indicated in the above note what I believe to be both primary and secondary causes of *reh* distribution. But no one can pretend at present to understand them fully, and it will be my duty as a member of the sub-committee to propose measures which may lead to a better comprehension of facts as well as remedies, a trial of which may appear to be advantageous. I venture to hold out a hope that the agent which has proved its power of removing *reh* from one stratum to another of the earth's crust, may in the exercise of that power be diverted from the work of destruction to that of restoration, and that some means may be found of inducing canal water to cleanse, not only that land which it has polluted, but that also which was subject to obstinate disease before canals were known.

E. C. BUCK,

Director of Agr. and Com.

Note by CAPTAIN T. HOWARD, R.E., Executive Engineer, Irrigation Department.

THE most probable explanation of the efflorescence of *reh* appears to be that the salts are present in the subsoil, and are brought up by spring water to within a few feet of the surface of the ground. The overlying soil becomes saturated by capillary attraction, and the water on rising to the surface is evaporated, leaving the salts behind. There is no evidence to show whether the motion of the salts below spring-level is upwards only, or lateral as well.

2. Excepting that chemical analysis is stated to have detected a small amount of *reh* in canal water, there is no reason to suppose that the *reh* brought up from below is increased from any other source, but its distribution over the surface is to a certain extent affected by running water, wind, and other physical causes.

3. The rise of spring-level in recent years has been caused by obstructions to drainage and by the percolation of canal water, partly from the fields over which it is spread, and partly direct from the carrying channels. Any cause which accelerates the rise of spring-level tends to increase the area of *reh*, and any cause which retards the rise of spring-level tends to prevent the increase of *reh*.

T. HOWARD, CAPT., R.E.,

Exc. Engineer, Irrgn. Dept.

Note by R. E. FORREST, Esq., Supdg. Engr., 1st Circle, Irrigation Works, N.-W. P.

THIS is a subject on which I write with the utmost diffidence. I lived for six years in the midst of the largest úsar plains in the North-Western Provinces, but I have not been able to come to any precise decision on the subject. I can only put down some general considerations that occur to me in the matter for what they are worth.

2. Canal officers need not now defend themselves against any charge of undue bias in favour of their canals. The days have gone by when they dwelt only on the wealth-giving, famine-saving side of the question.

The physical side of the question, that introducing a large body of water into a country, and not drawing on the subterranean reservoir as before, will make a change, has been long recognised and pointed out. I have therefore the less hesitation in stating my opinion that I think the effects of canals for good or evil are much exaggerated.

Note by R. E. For-
rest, Esq.

The Ganges Canal did splendid work during last year's drought, but how small the effect of the whole vast system to that of the rainfall in October!

If the people living on a dry sandy site have it turned into a quagmire, it cannot be good for their health. But that canal irrigation is a cause of epidemics, especially of fever, has now, I think, been given up. In the large equation of the health of a people, of epidemic diseases, where there are so many known and unknown elements, food, clothing, heat and cold, absolutely and in relation to one another, winds, electricity, the existence of a canal channel and canal irrigation, would in most cases be a very small factor.

In some places the canal has raised the water level enormously, in others not at all.

When the drainage conference took place five years ago, the rise in level of the well at Meerut was pointed to confidently as showing the action of canal irrigation. I ventured to point out then that when the wet years had past and the dry ones come round again the level would sink. The level has now gone down to the deepest ever noted, long before canals were made, and this notwithstanding that the canal irrigation is greater than ever.

The springs along the edge of the Soláni river, confidently held to be due to percolation from the canal, are this year dry.

It is now seen that the swamping in the Káli nadi in the Bhongaon pargana was not due to canals, but to excessive rainfall. In short, in this matter of spring-level the effect of the natural rainfall has been left aside altogether. It is much more powerful than canal irrigation.

Some measurements that we have made show how little the wells are affected by the running or shutting of the canal, how greatly by the rainfall. The canal may have great local effect, but not great general effect.

3. Reh tracts existed long before the canal, and now exist away from it. It seems to me that the causes that produced these great úsar plains, such as that at Aimáh, must be powerful ones, and working over long periods of time. Whatever may be the effect in some localities, canal irrigation does not seem to me an adequate cause for any great general production of reh. The canal has never produced reh where it did not exist before. Where no reh tract is found, naturally, the canal may produce swamps and marshes of the worst description, but not reh tracts.

4. That the presence of canal channels and introduction of canal irrigation must have an effect on a tract of country no one can doubt. But the extent of that influence is the real practical question.

5. Canal water may help to produce or distribute reh in three ways:—

1st.—By carrying it in solution. The water analysed by Mr. Ward was highly charged with the deleterious substances; in fact so much so as to make it doubtful whether it was not an exceptional specimen. The effects produced by it would have been quicker than they have been.

It is not known what the nature of the water along the various lengths of the Ganges Canal is at present. The salts in it may be more as it gets down to the point where it passes through the úsar tracts. The salts may not be in such quantity as to be injurious to vegetation.

The dense plantations that now line the canal, the vegetation along the edge of the water may enrich the water with vegetable matter and counteract the effect of the reh.

Channels passing through reh tracts would take up reh at first, but they soon line themselves with silt.

In the rains the drainage from úsar plains passes into canal channels, but at that time there is not much irrigation. The water passes away.

The general opinion seems to be that this is not the way in which canal water does much damage. It is not found that canal water produces reh in tracts when it did not exist before. It is not found that it produces more reh towards the tails of the terminal branches after passing through the reh tracts.

Note by R. E. Fox-
rlist, Esq.

It may perhaps want more time to do this. But on all these points what we want is precise information, the most important being the analysis of the water.

2nd.—By carrying it along the surface of the ground, washing it in from its place of formation into the good fields. This does happen.

3rd.—By supersaturation of the soil, by which "all water delivered on the surface, either by rainfall or from canal, instead of percolating downwards, and washing downwards with it the reh in the soil, remains stagnant in the soil, drawing the reh up from below to the surface by capillary attraction." This is generally held to be the main cause. Here it is evident that the amount of the rise of the spring level is most important. If this rise of level is up to a point below the depth to which this capillary action extends, if the line of saturation is below that of evaporation, then no harm is done. I do not know what the evaporation depth is.

6. If earth be taken from fields near a reh plain and put into a wooden box and saturated with water, and then allowed to dry in the sun, reh will appear at the surface; not so if holes be made in the bottom of the box.

7. What would be the remedy for each of the above forms of evil action, supposing it to exist?

1st.—If it is in the canal water, the only plan is to withhold the water, or make holes in the bottom of the box; have deep drainage. But with the small outfall this would be expensive. It is a question of locality. It would not be worth while for the Government to deep drain each field. The water must be withheld.

2nd.—Here the remedy is not to allow watercourses to be taken across reh-covered plains—in every way a most objectionable practice.

3rd.—Here, Colonel Brownlow pointed out, the real radical remedy is "the rapid removal of surface drainage, strict prohibition of canal irrigation, and substitution for it of extensive well irrigation."

I agree with this, as I agree with Colonel Brownlow in thinking that the rise in spring-level is far more due to the water laid on at the surface than to any subsoil movement.

In this connection the influence of the heavy rainfall has to be considered. It seems to me that the direct effects of years of heavy rainfall is much greater than that of canal irrigation. But we want observations.

8. The reh is found, in my experience, in the clayey or mattýar soils, and not in the bhúr or sandy. The great reh or úsar plains of the central duáb are the heads of the internal drainage lines like the Rind, the Sengar, the Kurwan, the Phura, and the Ahnya. There is a heavier rainfall on these tracts than in other places in the neighbourhood.

The drainage in them is at once rapid and slow; a rapid run off from the higher lands which edge the low úsar plains and jhíls, and a slow escape from the latter. The process of denudation by which lands are gradually deteriorated in quality by the good top soil being washed away, until the good soil (which over great part of this duáb is not very deep) is washed away altogether, is one that is in active working over large tracts, and which seems to have attracted but little attention. I believe great changes to have been wrought by it.

I have seen large plains where the sites of villages, the remains of groves (the height of whose roots above the surface showed where the former level of the land has been), the scattered patches of cultivation (from whose position it could be seen that

Note by R. E. For- the cultivation had once been continuous, and in which the actual process of degradation
REST, Esq. could be watched), showed them once to have been cultivated, which are now barren.

This process of rapid denudation and degradation is one marked and constant feature of every úsar plain I have ever seen. To what extent this may help to develop the reh by cutting away the good top soil to a stratum where the deleterious substance has lodged in excessive quantity, or by exposing more surfaces to the air, I cannot say. It may be merely that the reh by its crystallization makes the soil more friable and the more easy to cut into.

If a line be drawn across the duáb from Muttra to Ká-ganj, the high land on the banks of the Jumna in the Muttra district is seen to be sandy in character, the water in the wells is very brackish, and often unfit to drink, a slight efflorescence is seen in most of the well courses, the crops are very fine. The low land in the Aligarh division, on the same line, is marked by úsar plains, shallow wells, water good to drink, good clay soil. What is the connection between the two ?

Double cropping is a great cause of mischief. All the complaints made of increase of reh are in tracts where indigo is largely grown. The reason is that the indigo leads to more continuous irrigation of the land, and therefore to supersaturation and to double cropping.

9. The only special observations on reh along the Ganges Canal with which I am acquainted are those made by Mr. Buck and the present committee.

Mr. Buck's were careful, long-continued, and widespread inquiries. He has given the result in his thoughtful paper. As regards the influence of the canal he says—"In the course of my duties as settlement officer, I had, as I have previously stated, occasion to inspect the country on either side of the Ganges Canal for some distance (about 30 miles of which were in the Farukhabad district).

"The canal passes for the whole distance along the centre of a depressed dúmat watershed lying between parallel rivers, and comes therefore constantly into contact with úsar plains.

"I made special inquiries in every village whether the canal had impaired the fertility of cultivated land by the introduction of reh. In the Farukhabad district I only found two cases along the whole 30 miles where any marked effect had been produced."

I have lately marched down the Etáwah branch and up the Cawnpore. On the former I saw in many places where the soil was light the influence of the canal in producing swamps. On the latter, with the harder clay soil, the water seemed to have no influence on the gháils, and I could see no connection between the canal* and the reh fields. The reh was no greater, touching the canal bank, than a mile from it.

The only thing was that the reh seemed to have increased in the ehoki compounds.

Mr. Buck is of opinion that the reh is carried by drainage or other water along the surface, and that any sub-surface movement of the water has no great effect.

10. The points that occurred to me personally in the recent enquiry were—the small area affected, that the lands said to be injured all lay along drainage lines and in naturally unfavourable positions, that there were other causes as powerful for injury as the canal; that if an injured field lay a mile or so off the canal, in the intermediate space along the very edge of the canal were flourishing crops. With regard to the space between the channels, where their influence should be greatest, the úsar plains were broadly marked years ago, very much as they are now, and at the very apex, where the bifurcation works were put, because the soil was good, the soil still remains good.

The zemindars dwelt on the want of growth of grass on the úsar plains. I have observed this elsewhere, and think it is chiefly due to the drought of last year.

I think this tract of land should be examined and reported on each year, to see whether the grass does grow, the fields do recover themselves, or whether the *reh* spreads.

Note by R. E. FORREST,
Esq.

11. It seems to me that what is wanted is more exact, widespread, long-continued scientific enquiry into the subject.

What is wanted is—

- (1)—An analysis of the canal water at various points.
- (2)—An analysis of the water in the wells lying along a line extending across the *duáb* and passing through the sandy tracts on the banks of the rivers Ganges and Jumna and the *úsar* tracts between.
- (3)—An analysis of the soil along the same line.

The *úsar* tracts should be carefully mapped, so as to be able to trace any physical law that governs their lie and spread.

This work should be carried out by a specially qualified officer, an agricultural chemist and geologist. The enquiry should be a scientific one in fact, and apart from the complications and want of correct evidence that arise when it is connected with assessment of revenue.

A careful and systematic system of observations on the spring-level of the country should be laid down and carried out.

12. In tracts in which *reh* is said to be spreading, its present limits should be marked down exactly, and a careful watch kept and annual enquiry made.

In tracts where canal irrigation is being introduced for the first time, as in the Deoband *duáb*, the limits of all existing *úsar* tracts should be most carefully noted down for future comparison.

13. Experiments should be tried to see if surface drainage, or deep drainage with copious irrigation, will be effective. I confess that, judging from past experiments, I have not much hope of the reclamation of *reh*; but the experiments would at all events extend our knowledge on the subject of *reh*.

Above all, where it is in any way held that the mischief is due to canal irrigation, the canal irrigation should be cut off.

14. To answer the questions specifically put by the President :—

- (1.) I think not.
- (2.) (a) and (b).—I think with Colonel Brownlow it would be due to over-irrigation. The subsoil movement must be slow.
- (c).—This would have an injurious effect if it led to super-saturation.
- (3.) Mr. Buck found none. But a high canal level in certain soils produces swamps and waterlogging, and may produce *reh*. We want more observations.
- (4.) Observations wanted.

Under II.—

- (1.) Always.
- (2.) The main canal line cannot be changed. The alignment of distributaries is being improved.
- (3.) I think this would be a great economic error. It would throw away a great part of the advantage of the canals.

Mere low lift would not lead to any great economy of water; and if the lift is made so high as to enforce great economy, there would be a great waste of labour and

Second Note by
H. B. MEDLICOTT,
Esq.

money, and, a point of great moment, the irrigation could not be so easily and quickly effected in a year of drought. It would cripple irrigation then.

As it is, in the parts of the Ganges Canal which run through the *reh* tracts, the proportion of flow irrigation is only about 50 or 60 per cent., and not likely to be more than this.

The true remedy is the greater economy in the distribution of the water, to which the attention of canal officers is now being directed.

Greater attention is being paid to the position and size of the minor water-course heads and distribution pipes.

The making of the main carrying channels has hitherto been the chief object of care, thought, and attention. It is now being recognised that the passage of the water from these channels to the fields is equally deserving care, thought, and attention.

Regulation and economy and judicious distribution to the minutest fraction is the true remedy.

The rates of flush irrigation should be raised.

More power should be given to local canal officers to reduce former supplies.

Under III.—I have stated this before.

R. E. FORREST,

Supdg. Engr., 1st Circle, Irrign. Works, N. W. P.

Second Note by H. B. MEDLICOTT, Esq.

THERE are some passages in Mr. Ibbetson's note calculated to obscure or pervert a feature of the case I have been at some pains to exhibit, even undertaking for this end the unpleasant task of pointing out the men who are *ex officio* (although blindly so) pledged to be thus obscurantists. The great canals are surely intended to last through a long spell of the human period, and we are therefore bound to contemplate rigorously what must or may be their effects, under existing conditions, within at least the next two or three generations. The "immediate" and "at present" in the first sentence of Mr. Ibbetson's clause on the sources of *reh* makes the statement very nearly correct, but not quite, as a general proposition; for *reh* can occur where subsoil water, in the sense used, does not exist, of which an instance is given in the preceding clause of the note, where *reh* is described as deposited directly from irrigation (from deep saline wells). The second sentence of the same clause is more dangerously incorrect, for it is just such a statement as is seized upon and repeated *ad nauseam* by those whom it suits. In its form of a general statement the (superficial) obviousness of the conclusion is most fallacious; for, *first*, irrigation diffuses and disguises *reh*; in an irrigated and cultivated field there might be more *reh* than in an adjoining unirrigated soil, the surface of which was white with salt; or, *second*, the fact of a *reh* area being *ipso facto* the most propitious place for the exhibition and accumulation of the salt does not show that the slow process of formation is not going on from irrigation in an area close by.

2. The little calculation in the 3rd paragraph of the same clause is obnoxious to the same objections. One inch of *reh* sounds like an imperceptible quantity next to 2,405 years; but a *reh* soil may contain no more than a tenth of an inch of solid *reh*, which at once reduces the force of the remark to a period of 240 years. But this is not all: from the form and intention of the statement, which scrupulously omits the tiny item of evaporation from the canal surface, it would be understood that the whole of the canal water was taken into account as 26 inches of irrigation. Indeed, I should have understood this to be the meaning, except for the distinct statement in clause 9, that "a quantity equiva-

lent to 62 inches a year is put on to the field;" for Mr. Ibbetson, who bears such positive testimony to the great extent of percolation from the canal and its *reh*-producing action, could not be unaware that only a portion of the canal water can be regarded properly as irrigation water. I am credibly informed that something like 60 per cent. of the water that enters the canal is unaccounted for by irrigation, and must be set down to loss by percolation; and more or less of this enormous quantity is disposed of by evaporation from a shallow water-table. This surely should have been taken into account in the little calculation illustrative of the possible direct effects of canal water upon *reh*. As it stands, that calculation is mischievously misleading.

Second Note by D.
IBBETSON, ESQ.

3. I am the last to deny the first facts of the case, that the *reh* scourge existed widely before the canals were thought of, and that *this reh* constitutes immensely the greater part of what has now to be dealt with. I only press for a clear recognition of the fact that *under existing conditions of climate and of agriculture* destruction by *reh* must result in a few generations from canal irrigation even where no *reh* was originally present. The measures to be adopted are immensely affected by the recognition or not of this effect. Rain water (so far as has been recognised) brings only small quantities of carbonic and nitric acids, the effect of which in producing *reh* is limited to the very small proportion of alkali remaining as silicate in the soil; whereas canal water carries the ready-made article.

4. I would ask for further evidence upon the opinion confidently given that the rise of the water-table is due more to flooding of the surface than to percolation. Mr. Ibbetson asserts it (clause 9) as a conviction, having in the preceding paragraph but one given an amazing instance of great percolation. Colonel Brownlow (note of 10th April, 1877) gives it as a conclusion from experience, but only gives rather doubtful assertions in evidence. I doubt the correctness of the view, and it is a most important point to settle. If the water did penetrate so easily from the surface, the *reh* scourge could hardly be what it is. The non-penetration of surface water is a generally accepted condition of *reh* production.

The 9th April, 1878.

H. B. MEDLICOTT.

Second Note by D. IBBETSON, ESQ.

HAVING read Mr. Medlicott's note, I would add one word to my own by way of precaution against a possible confusion of two points really separate. In sections 14 to 16 of his memorandum Mr. Medlicott gives his reasons for disapproving of the proposal to carry canal water at low instead of, as now, at high levels. Unfortunately, he connects with this proposal the substitution of lift for flow irrigation, which is the one remedy which I most insist upon. I need hardly point out that the latter scheme in no way necessarily involves the former. In section 9 of my note I distinctly protest against the carrying of canals along the lowest levels; and in section 11 I point out that, under my proposal, the water would be *distributed*, as at present, at a high level, but, when once brought to the spot, would be delivered into a reservoir or well, from which the cultivator would have to lift it. As all Mr. Medlicott's arguments point only to the desirability of retaining the command of high levels in the distribution of the water, I think I may assume that his objections, which carry all the weight due to scientific authority, do not apply to my proposal, and that his mention of the substitution of lift for flow irrigation in this connection was merely incidental.

Mr. Medlicott's views, as expressed in the paragraphs above quoted, are so diametrically opposed to those generally held on the subject, and amount to so sweeping a condemnation of the steps that have been, and are being, adopted to remedy the evil, that, while fully recognising the authority with which he speaks, I cannot refrain from saying a word on the subject. If my remarks induce him to point out where I am wrong, they will not have been thrown away. Mr. Medlicott's reason for preferring to keep the canal water at a high level appears to be that percolation and hydraulic

Third Note by H. B.
MEDLICOTT, Esq

pressure from the canal tend to raise the sub-soil water to a point where it would be within reach of practicable drainage. He practically says that the higher the water-table is the better, as it will be more easily got at. On the view of this subject, *any* cause that tends to raise the sub-soil water-level is, *pro tanto*, an advantage, and to be encouraged. Now, where the water is below the maximum depth from which it can rise by capillarity, the surface is safe from *reh*, and it would probably be wise to leave matters as they are. Where, on the other hand, the water is at a depth less than that maximum, capillary action will go on unchecked, however active drainage may be, so long as the water-table remains within the limit of capillarity. To reduce it below that limit, drains must probably be at least 15 feet deep everywhere, which in a district like Karnál, with a fall of a foot in a mile and no outlet, would, I fancy, be difficult. Further, if the drains are to be below the existing water-level, there would appear to be no advantage in raising the latter still higher. I should have thought that drainage would have done much more by intercepting and carrying off the salt-impregnated water as it soaks downwards on its way from the surface to the main body of subsoil water, than by carrying away a portion of the latter after the salts so brought down have been diffused throughout the mass. To effect the latter object, the depth of the drains would have to be enormously increased; while the advantage gained would surely be neither sufficiently certain nor sufficiently great to warrant the deliberate intensification of all sorts of evils, which it is admitted that a further rise of the sub-soil water must enhance.

D. IBBETSON,

Settlement Officer, Karnál.

The 10th April, 1878.

Dated Calcutta, 31st May, 1878.

Note by H. B. MEDLICOTT, Esq.

I HAVE now the honour to forward for the information of the Committee the results of the examination of the samples of soils and waters I brought with me from the North-West. Although few and incomplete (for an itinerant and miscellaneous committee is not a favourable occasion for making studious observations), these assays give more exact information than usual. In samples sent for analysis it is rarely stated how the top-soil was taken, whether scraped from the surface or carefully cut square to a certain depth; and thus the quotations of *reh* in soils vary from 1 to 40 per cent., according to the bias of the calculator.

2. The determination of the salinity of the sub-soil waters is also a new point of interest. Of each soil, half a pound of the mixed earth was treated with two litres of water, and one litre taken for examination and evaporated to dryness, so as to take up only the permanently soluble alkaline salts which constitute the *reh*. The assays were made in the Geological Survey Laboratory by Mr. Turner, under Mr. Mallet's supervision.

REII—Estimates of soils and waters.

					Soluble salts, parts in 1,000.
Akrahad (Aligarh), field No. 93 :—					
A {	1.	3 inches cube of soil, including a thick crust of <i>reh</i>	...	...	18.80
	2.	Earth 2 feet below surface from a freshly dug hole within 6 feet of No. 1, surrounded by the same surface <i>reh</i>	...	...	2.44
	3.	Earth 6 feet from surface in the same hole	...	...	1.56
	4.	Water at 9' 3" in same hole	...	...	0.466
	5.	Water at 9' 3" from a hole 60 yards to east of last, at the same level, in a field bearing a poor crop	...	...	0.57
Hydernagar, a hamlet of Nanon (Aligarh), field No. 769 :—					
B {	6.	6 inches square by 2 deep from a small (6 feet square) bare spot, but without efflorescence, in midst of a rich crop, on same level, and equally irrigated from a well; water 6 feet from surface, not saline to the taste	...	...	3.88
	7.	A like sample from close by, under rich crop	...	...	0.45
Dasnah, the field of Mr. Michel's experiment :—					
C {	8.	3 inches cube of soil, no visible <i>reh</i>	...	...	1.13
	9.	Kunkary earth four feet from surface	...	...	1.74
	10.	Water 6 feet from surface	...	...	0.44
	11.	Clay film (<i>papery</i>) from a dry channel close by	...	...	4.07

Sent by Captain Harrison, R.E. :—

D	12.	Sháhpur (Cawnpore), field No. 199, "surface of úsar land in which an experiment in sub-soil drainage is being made"	...	...	...	...	2.73
	13.	Earth at 2 feet from surface	...	...	...	...	1.29
	14.	Earth at 5 feet from surface	...	...	...	...	1.51
	15.	Water at 9 feet	...	...	...	...	0.542

Guráoli (Farukhabad), field No. 322 :—

E	16.	Surface	...	...	...	...	9.20
	17.	Earth 2 feet from surface	...	...	...	...	2.73
	18.	Earth 5 feet from surface	...	...	...	...	0.80
	19.	Water 9 feet from surface	...	...	...	...	2.432

Quoted from Jour. Royal Asiatic Society, London, Vol. XX., p. 336, 1863 : or Sel. Govt., India, P. W. D., XLII, p. 43.

Garden at Roorkee :—

F	20.	4 inches cube of soil	...	...	...	...	4.00
	21.	Sub-soil just over water	...	...	...	...	2.00
	22.	Water 5 feet from surface	...	...	...	...	0.069
G	23.	Ganges at Hardwár	...	...	...	...	0.0108
	24.	Calcutta pipe-water filtered from Hughli	...	...	...	...	0.0295
	25.	Thames at Twickenham	...	...	...	...	0.0630

No. 1 is a sample of one of those worst *reh* covered fields seen by the committee, yet when distributed through only three inches deep of soil, it is little more than may be present in a fertile soil under fair conditions. This group A. shows the steady concentration of *reh* towards the surface.

Nos. 4 and 5 are interesting as showing that the distribution of *reh* under ground has no direct connection with its appearance at the surface ; the contrast at the surface being due to local differences of capillary action and evaporation.

Nos. 6 and 7 show clearly that the barrenness is due to the presence of *reh*, but a mechanical comparison of the samples does not show any appreciable difference to account for this. These were, however, taken only to a depth of 2 inches.

The contrast between Nos. 17 and 18 is quite accounted for by their different textures : No. 17 contained only 43.35 per cent. of fine sand and held 2.75 per cent. of moisture, while No. 18 had 10 per cent. coarse sand, 55 per cent. of fine sand, and 1 per cent. of water.

The samples 4, 5, 10, and 15 give an average of about $\frac{1}{2}$ per mille for the salinity of the *reh* water of the upper water-table. No. 19 seems to be an exceptionally bad case. A sample of very bad water taken by the committee at 6 feet from the surface near Kunakpur, close to the Rind, was unfortunately lost in transit.

3. I am glad to have this opportunity of adding a few explanatory remarks to my former notes, as I have learned, in correspondence with Mr. Ibbetson, that I have not sufficiently guarded against possible misapprehension of my views ; that in laying stress upon what every one else is disposed to ignore—namely, the direct action of canal waters—I might be taken to ignore what is most apparent, the existence of *reh* independent of canals, and thus frustrate my purpose by giving apparent grounds for an imputation of unreason. If the matter were not of such importance I should not care to notice such self-deception, for in my first note to the committee I gave explicit prominence to the accumulation of *reh* independently of canals as the most immediate source of danger ; and even in my original note (in 1862), the case (F. in foregoing list) in which I demonstrated that *reh* soil is, in a comparatively short time, derivable from water as pure as canal water, is strikingly distinct from the other cases described by quotation, as I had then never seen an old *reh* area.

4. It is worth while to exhibit how men blind themselves upon so important a feature of the case under investigation. A guess is made, say one inch, as an average amount of salt for *reh* land. It is then shown by correct arithmetic that it would take more than 2,000 years to produce that amount of *reh* over the whole irrigated area by the evaporation of the whole volume of canal water. This easy *reductio ad absurdum* of our fears of canal water is eagerly accepted by those whom it suits, and unfortunately some exact information is needed to confute it. The one inch of *reh* seems a trifle ; but it is about 20 times more than occurs on bad *reh* ground (see No. 1 of list), and about 100 times more than is enough to produce sterility (see Nos. 6 and 20). The demonstration is, moreover, often made without regard to the mode of distribu-

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tion of *reh* in the ground; whereby the pollution of the sub-soil water, effected by the total evaporation over the whole area, takes effect as *reh* over only a portion of the area. Thus, from a correct estimate of the facts, it is apparent that within a very few years extensive destruction from *reh* might result from canal water only.

5. My entire conviction of the correctness of this judgment has made me persist in urging it upon those who would ignore this consideration in dealing with the *reh* question. Because *reh* does exist extensively without canals, it is seemingly rational to assume that what appears in connection with canals is derived from the same source, and that the canal water need only be considered as a vehicle for this independent *reh*. Those who hold this view would fearlessly introduce canal irrigation wherever it had been proved that *reh* was not present in the ground; and they are now only facing the partial question how to control the accumulated *reh*, without a thought of the unfailing source of it contained in the "perfectly harmless" fluid they recommend as the panacea for the ills of India. All this is undertaken boldly without any attempt at understanding how *reh* comes into existence—an irrational mode of proceeding worthy of the dark ages—and transparent fallacies are accepted as convincing arguments. Because canals work harmlessly in certain areas, it is said the canal water cannot be guilty, as if *reh* was not a result of a complex combination of conditions. To me the question before us is not how known *reh* tracts can be doctored, but how is irrigation safely practicable in Upper India? And the more I consider the question, the less confident I feel of a favourable and practical answer.

6. No sane man will attempt a solution without forming some opinion regarding the origin of *reh*; but every one seems content to accept the *reh* as an ultimate fact—that there it is—as much an original ingredient of the ground as the clay and sand. Now I consider it demonstrated that this view is false, and that an origin is assignable for *reh* which introduces the gravest apprehensions as to the possible results of canal irrigation. The present chief store of *reh* is in the saline sub-soil water, the upper water-bed, found more or less all over Upper India (see Nos. 4, 5, 10, 15, 19, 22). Beneath this, at depths of from 60 to 100 feet, sweet water is found containing no more salt than the canal water, which is very pure (No. 23). Now I consider it certain that these upper deposits were originally as free from those salts as is now the alluvium of the delta; and that the present state has been brought about in the course of generations slowly, but with increasing rapidity, owing to the total subversion of the natural climatal conditions—chiefly by the total destruction of forest vegetation. The explanation is simple: every soil contains some *reh*, and all percolation water from soils is also contaminated by those salts, which are the refused products (the parts unassimilated by vegetation) in the very slow process of formation and consumption of soil. Unless removed it must accumulate; and the natural process of purification is a certain necessary amount of percolation and ground drainage, the pure rain water passing through the soil, carrying off any injurious excess of these rejected salts. If the washing process is sufficiently free to ensure a certain discharge of this percolation water by natural sub-soil drainage, there will be a constant dilution and removal of the sub-soil water; but if the percolation through the soil is no more than to restore what has been dissipated by capillary action and evaporation during the dry season, the *reh* will go on accumulating in the upper water-table; and such has been the condition of Upper India for many a day.

7. This is how the *reh* was lodged where we find it, and the prime mover of the process is now more powerful than ever. The immediate effect of the canal upon this state of things is to raise the level of the impure upper water-bed within reach of more active evaporation, resulting in the profuse efflorescence of *reh*. Now, the questions whether the country is to be saved, or to be ruined, within 20 or 100 or 500 years, depends upon the one question whether we can artificially restore, or supply an equivalent for, the natural circulation of the ground water. Will all the water we can pour over or under the ground supply all that evaporation can take, and also an excess

enough to restore the needful under ground discharge for purification? For if not, the canals may be looked upon as *reh* feeders.

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8. There are little or no data for answering this question: a comparison of the salinity of the sub-soil water before the canal was started and now would probably have given a hint upon it. It is certain that the canal does, to some extent, force the sub-soil drainage, for the natural drainage channels that used to be dry in the hot weather now carry water at that season. An examination and comparison of this percolation water during successive seasons should give useful indications. This is one of the most hopeful features of the case, suggesting that by artificial drainage it might be possible, in time, to get quite rid of the present saline sub-soil water. To take full effect from this means would require that the canals should run as high as possible; but on the other hand, this would aggravate greatly the most pressing present form of the evil, and the most favourable condition of *reh* production, by raising the water within reach of active evaporation; and accordingly the lowering of the canal level was strongly advocated by several members of the committee; it was the remedy proposed by Colonel Baird-Smith in 1858 with reference to the Western Jumna Canal.

9. Here, again, there are no observations to indicate a possible compromise between these two conflicting objects, to show the rates at which evaporation and capillarity can draw water from different depths. If the reduction of the saline water by percolation of canal water and drainage were taking place at a rapid rate, it might be advisable to endure the temporary destruction of certain portions of the land; but it is much to be feared that evaporation at present has the upper hand on account of the enormously greater extent of its surface over that of percolation, although, of course, this disproportion could be reduced by drainage cuts. It is a matter of the first importance to ascertain the tendency of this condition, by continuous testing of the sub-soil water at selected spots. It is possible, with all this increased exhibition of *reh*, that the old store of saline water may really be undergoing depletion through the under ground action of canal water. I do not believe it is so at present, but it may be possible, by ground drainage, to turn the scale. If this should not be possible, the store of *reh* will certainly increase unceasingly, for it is not possible to lower the canal water-table below the range of all capillary action. The only question then remaining would be the possibility of cultivation flourishing above a briny water-table through the management of irrigation and sub-soil drainage.

10. There is another aspect of this canal question that is not obvious, unless through a correct apprehension of the cause of *reh*. Supposing the effect hoped for attained, the purging of the sub-soil water by under ground percolation from the canal is not equivalent to restoring the natural water-circulation, nor is the restoration completed by irrigation. The profuse waste of the rainfall was a first step in the accumulation of *reh*, and the outpouring of canal water does not affect the causes of that waste. If the irrigation water is disposed of in the same way as what remains of the rain water, i.e., by evaporation, the conditions of *reh* production would remain as before, with one important difference—that the canal water contains *reh* while the rain water does not. It would, I think, be possible to have a *reh*-destroyed soil over a purified sub-stratum; but the remedy for this aspect of the case is more certain, though it may be difficult to attain under the conditions of Indian agriculture. Colonel Corbett has fully pointed out the advantages to be certainly gained by deep cultivation in utilising and distributing water at the surface: and it may be necessary for some soils to supplement this by sub-soil drainage, as has been so forcibly advocated by Colonel Thomason, R.E.

11. To those for whom *reh* in all its bearings is an occult question—and the history of the *reh* forms a curious commentary on the intelligence of the period in India—the great resource seems to be the institution of experiments. The word at least sounds well, and any one can make an experiment according to the light that is in him. There are two things to be said on this score: that there is need for careful

Proposals by Sub-Committee.

observations and some experiments I have sufficiently pointed out ; but it is of the first necessity that these should be conducted on the spot by some one who has a scientific knowledge of what he is about. There would then be some chance of the matter coming to an issue, instead of drifting helplessly, as it has been for the last quarter of a century. The other point is that experiment should not be allowed to postpone all action, now that a rational explanation of the main phenomenon has been given. I do not fear that that explanation will be disputed by competent judges or materially altered by further investigation.

12. The one measure that is beyond all dispute in this matter is the endeavour to mitigate the prime source of all the mischief, the extreme of heat and drought to which the *reh* tracts have been subjected by the total destruction of forest vegetation.

Proposals by Sub-Committee.

MR. MEDLICOTT,	} <i>Members.</i>
„ BUCK,	
„ FORREST,	

1. *Deep drainage*.—The committee have already proposed that in the Sikandra Ráo pargana a deep drainage cut known as “the Akrahad cut” should be completed, also that drainage of the Rind river should be improved. The effect of the operations should be observed.

2. A *reh* map should be made for the North-Western Provinces, and, if possible, also for other provinces in which *reh* is prevalent. This is necessary—

(1) in order to obtain a comprehensive knowledge of the surface distribution of *reh* ;

(2) in order to watch its increase or decrease.

3. The *reh* map suggested in para. 2 should be complemented by a map of the surface drainage of the country, in which levels should be marked, without which the connection of surface drainage with the distribution of *reh* cannot be ascertained.

4. The level of the underlying water-table should be obtained at different seasons of the year, in order to ascertain what relation exists between the depth of the water-level and the surface distribution of *reh*.

5. Precise experiments should be made of the nature indicated by Mr. Modlicott in para. 20 of his note, in order to ascertain the limits within which the action of the sun induces capillary attraction. This experiment should be made both at Roorkee and in the Sikandra Ráo pargana.

6. A series of agricultural experiments extending over a sufficient number of seasons to produce reliable results should be undertaken with the view of ascertaining if any method of local treatment in the reclamation of *reh* lands is effectual.

These experiments should comprise—

Arboriculture.		Flushing.
Surface drainage.		Manuring.
Subsoil „		Growth of special crops.

7. The sub-committee suggest that the agency by which the measures above proposed are to be carried out in the North-Western Provinces should be—

(1)—*Deep drainage*—by the Public Works Department in the Irrigation Branch.

(2) *Reh map*—by the Agricultural Department, under whose orders a sufficient staff of surveyors should be placed.

(3) *Drainage map*—by the Survey Department.

- (4) *Level of underlying water-table*—(a) by the Agricultural Department, through the subordinate revenue machinery referred to above, who will record depth of water of wells in each village at stated intervals. (b) by the Canal Department in irrigated tracts.
- (5) *Mr. Medicott's experiments*—by Captain Cunningham at Roorkee, and by a canal officer in the pargana of Sikandra Ráo.
- (6) *Agricultural experiments*—by the Agricultural Department in the Sikandra Ráo pargana, a subordinate officer being placed by the Public Works Department in the Irrigation Branch at the disposal of the Director, Agriculture and Commerce, for taking charge of the experiments.

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8. The sub-committee suggest that charges on account of the proposed operations be met as follows :—

- (1) *Deep drainage*—as an ordinary charge in the Public Works budget.
- (2) *Reh map*—Details will be supplied by the subordinate revenue department without charge. Not less than a sum of Rs. 2,000 will be required annually for a special supervising staff and for preparation of map, pay of mappist, &c.
- (3) *Drainage map*—by the Survey Department, who should be asked for an estimate of cost.
- (4) *Water-table levels*—by the subordinate revenue establishment without extra charge.
- (5) *Mr. Medicott's experiments*—A small sum will be required for contingent expenses. Mr. Medicott and the Canal Department will be asked to submit estimates.
- (6) *Agricultural experiments*—A grant must be made sufficient to defray the cost of experiment, say not exceeding Rs. 3,000 a year in addition to the salary of the European subordinate, whose pay will be met by the Public Works Department in the Irrigation Department.

A sum should also be allowed from the provincial arboricultural grant for any extensive tree-planting that may be considered desirable.

H. B. MEDLICOTT.

E. C. BUCK.

R. E. FORREST.

Note by H. B. MEDLICOTT, Esq., on proposals of Sub-Committee.

I HAVE the honour to return herewith the statement of proposals drawn up by yourself and Mr. Forrest for submission to Government through the President of the Reh Committee. They indicate nearly all that is required, and I have only to add two suggestions that seem to me of some importance.

2. Additional facts would no doubt be obtained by the method proposed, yet most inadequate to the labour, cost, and time expended, and to the urgency of the occasion. Observation and experiment cannot be profitably made by men, however otherwise intelligent, without any scientific knowledge of the matter under investigation. The almost total absence hitherto of this element in *reh* investigation is the most

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instructive point of its history; and I would express a hope that the Aligarh committee may mark a turning point in this respect. It is sufficiently evident that the element I specify is not to be provided from local resources from the Revenue or the Irrigation Department, yet the resulting information will depend chiefly upon the amount of informed intelligence applied from the beginning. Unless the proposed experiments are conducted by some competent head, the question will drift helplessly, as it has up to this day. I would, therefore, advise that a well-qualified agricultural chemist be engaged for five years under the Department of Agriculture, to devote himself to this special investigation. As now instructed, a qualified man of this stamp would know enough of geology to take in that consideration, and I shall always be most willing to consult with him in the work. I may mention that quite lately an application was forwarded by the Secretary of State, through the Department of Revenue, Agriculture, and Commerce, for the post of chemist to the geological survey. I did not think the candidate fully qualified for the work of this department, but his testimonials certified to qualifications so suitable for the *reh* investigation that I am induced to mention the circumstance.

3. The second suggestion I have to make is related to that already given. The proposals forwarded make no mention of, much less provision for, the chemical work connected with this investigation. The few analyses I have made, or can make, only serve as indications to what should be made. A great deal of rough assay work will be required to determine various important points: the salinity of the subsoil water; the relation in degree and kind of its salinity to that of the *reh* grounds of the same districts; facts illustrative of the qualitative distribution of the *reh*, the variable proportions of the salts composing it; the testing of drainage waters of different seasons, and a host of special tests in connection with the agricultural experiments. The only question is whether one man can accomplish all that has to be done. The view I take of the *reh* question, and its consequence to the country, may seem exaggerated to those who do not adopt that view; but surely even the chance of such consequences would warrant every precaution in seeking to avert them.

4. When the examination of the samples I brought with me is completed I will submit some further remarks on the question.

CALCUTTA, }
The 6th May, 1878. }

H. B. MEDLICOTT,
Supt., Geological Survey of India,
Member, Sub-Committee.

Copy of a letter from F. N. WRIGHT, Esq., Settlement Officer, Cawnpore, to the Commissioner of Meerut, dated the 22nd March, 1878, being a report on the injury caused by reh in parganas Akraabad and Sikandra Rao, in Aligarh district.

IN accordance with the instructions received in your No. 37, dated 27th February, 1878, I have inspected the villages shown in the statement attached, in which it was alleged that serious injury had been caused by the increase of *reh* exudations. As my attention was specially directed towards the necessity or otherwise of any interference in the recently revised assessments on that account, I concerned myself less with the scientific causes of the origin and increase of *reh* exudations than with the existing conditions of the several maháls, with the object of a re-adjustment, if necessary, of the revenue in the light of those conditions.

2. It was, however, impossible to avoid paying some attention to facts which were alleged, during the course of my enquiries, to have caused the mischief which gave rise to the present investigation, and to the probability or even possibility of

that mischief being checked or finally remedied. What I therefore here record has no pretence to scientific value, but as the outcome of the statements of hundreds of independent witnesses may be worth some consideration.

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3. The universal consensus of opinion attributes the origin of *reh* in its present form—that is, excessive surface efflorescence—to the saturation of the soil, owing to the rise in water-level since the construction of the canal branches (between which the tract most injured lies), such saturation being exaggerated by the heavy rainfall of 1873, 1874, and 1875. The interruption of natural drainage courses and the profuse use made of canal water in irrigation have been additional causes of the mischief. I have no positive information as to the depth of water from the surface previous to the construction of the canals; the old survey maps are not forthcoming, and neither the old settlement reports nor Mr. Hutchinson's statistical memoir give any data on this point. Mr. Smith in his report speaks generally of the water-level being formerly 20 to 25 feet below the surface: the marks of the old bullock-runs to the wells would show it to have been certainly eight, if not ten, feet lower than it is now, and the fact that the water-level rises gradually but distinctly as you leave the canal southwards confirms the above impressions. The depth to water is now 14 feet under the most favourable circumstance in the villages which I have inspected, is 9 or 10 feet on an average, and is as near the surface as 6 feet in some few instances. The water-logging is beyond doubt. In one instance a village site (Amosi) was removed bodily to higher ground because the very fire-places became useless from the moisture oozing from the soil. In other instances similar assertions were made, but did not admit of such certain proof; but I myself saw water oozing up through the ground at Jau, where the canal was running full above the level of the surrounding country.

4. All the soil of the *doab* which is not pure clay (called *chiknot* in zila Aligarh, in other districts *matyar*), or does not possess a large admixture of sand (called in Aligarh *pilia*, in other districts *shar*) and which is generally known as *domat*, is much intermixed with large patches of waste known as *usar*, and contains with its adjacent *usar* a large proportion of salts. In the *usar* they are present in such excess as to render it utterly sterile; in the culturable and cultivated land they are latent and harmless up to a certain point. The excessive moisture referred to in the last paragraph has the effect of disintegrating and loosening the soil, so as to allow of capillary attraction being actively in progress. Under the special conditions of a heavy rainfall succeeded by bright hot weather, the *usar* becomes covered with a white snow-like efflorescence; and in cultivated lands, in places favourable to the action of the necessary agents, moisture and radiation, blotches or bare places appear, the area of which extends year by year till the whole field becomes not worth cultivating.

5. The spread of what I may call the infected area is gradual. Out of the thousands of fields I have seen affected with *reh* the very largest proportion are those actually contiguous to *usar*, which appears to be eating into the field; but in the same fields will be seen bare patches, and occasionally in fields removed some distance from *usar* the same indications are found of gradual deterioration. Again, some fields appear to be sickening over their whole area, though only isolated portions are destroyed; others, on the other hand, are bearing splendid crops everywhere, except where absolutely destroyed.

6. The villagers attribute considerable influence to the wind as an agent for propagating the mischief. In the hot months, they say, the wind blowing over places covered with this light impalpable efflorescence becomes laden with clouds of it (like a snow-storm with us, a dust-storm with them), and deposits its burden on the fields first reached, and thus commences the mischief. Of the truth of this assertion there can be no doubt, so far as it goes, for fields to the east of *usar* plains are invariably attacked on their westernmost edge.

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7. Water to a certain extent is also another agent in the spread of *reh*, but the villagers speak less of this and pin their faith almost universally to the excessive moisture in the soil "since the canal came," and, if pressed, "since the heavy rains of 1873-74."

8. There is, in my opinion, no remedy but to reduce the water-level; if this is not done, the evil must increase. A dry year like the past may check its progress, but even the ordinary rainfall will bring it into renewed activity.

9. The *modus operandi* adopted by me was as follows :—A thoroughly experienced munsarim marked the affected spots, however small, in every field. This I found had been done with remarkable accuracy, the exact configuration of the injured area being correctly delineated. I myself inspected every village thoroughly; not only the *reh*-affected portions, but the whole as if *de novo* for assessment. I investigated transfers, rentals, arrears of rent, &c., and endeavoured to acquire such information as to the circumstances of landlord and cultivators as would throw light on the allowance necessary to be made for deterioration, if any. I have carefully analysed the causes of decrease of rent-roll (where found), and especially the arrears of rent, with the view of ascertaining if they could be directly attributed to the effect of *reh*. In many instances this was most unmistakably the case, but in others I found that cultivators holding all good land and with no *reh* in their fields were in arrears; in others the area affected by *reh* would be trifling, but arrears heavy; in others, again, the patwari asserted that the heavy arrears were in no way due to *reh* (though *reh* was injuring the village), but to the fact that the zamindars mixed up their banking and rent accounts, credited receipts to the former, and showed any balance due under the head of arrears of rent—that is to say, the ordinary condition of indebtedness in which the cultivators usually are was utilized as a means of holding arrears over them and keeping them in the landlord's power. Comparison of the area cultivated now and at settlement is also misleading, for in many instances the area held by occupancy tenants, though actually destroyed, is entered in their names, and they still go on paying rent for it.

10. It is easy enough, as Mr. Smith admitted in his report, to suggest what should be done with the area actually destroyed, but the extent of deterioration beyond that area it is most difficult to estimate. The cry of "diminished produce" is raised in every village, good or bad. Nothing but a long course of experiment, or at least observation, would verify the truth of this assertion. For convenience of comparison of the condition of the village as it was at Mr. Smith's inspection and as I found it, I have given his notes, as well as those recorded by myself at my inspection in adjoining columns. The chance of a season over-cropping double-cropping, and in this year the fact that much land sown with *khurif* was roughly ploughed up and sown again with *rabi*, all tend to make an estimate of the degree of deterioration (if any) most difficult. In one case, I have said, the *maurusi* cultivators will hold on, paying even for land utterly destroyed, and the rental therefore suffers no diminution (they all say they did not know they could sue for abatement): in another, *ghair-maurusi* will throw up the land even slightly affected by *reh*, and the zamindars will be able to let it only at a reduced rate. In one village the result of the constant drenching of the fields with canal water, and repeated cropping with indigo followed by cereals, is plainly visible;* in another where canal water is never even taken the same appearance of deterioration may be seen. It is worthy of remark that there is a decided tendency to return to well-irrigation where possible, and limit irrigation to the cultivation of indigo and cane.

11. It should be remembered also that the attention of the people has been drawn to the interest now displayed in the question of the spread of *reh* for now two years past. It would not be a matter of surprise if a zamindar in some instances, with the idea that something would come out of all this investigation and enquiry,

* Arrears are heaviest in indigo villages.

should endeavour to improve his case and leave some of his worst land uncultivated for the present. This is commonly done at settlement; the worst land is so valueless that the zamindar can forego his rental for the present in hopes of future profit. By far the largest proportion of land thrown up as affected by *reh* is in the very worst situation—scattered fields in *úsar* or in district tracts near the river; and it is difficult when a field has been out of cultivation a year or two to judge by the eye whether it is absolutely unculturable or not. I have been most careful to show only the land unmistakably destroyed, and to show as affected land only that distinctly deteriorating from the effects of *reh*. Land near village sites has been destroyed by the saline wastings from the houses or saltpetre manufactories; the villagers call this salt “lon” and distinguish it from the *reh* of *úsar*; but it sterilises the land, unless indeed, tobacco could be grown on it. *Khari* could be made from it, but the facilities for making table salt forbid the issue of licenses. The severest loss is that of grazing lands, which it is almost impossible to estimate.

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12. Land, then, absolutely destroyed has been deducted from the cultivated area. Land affected by *reh* has been shown in two classes: (1) severely affected, where a large portion of the area has been destroyed and the remainder is going and must go; (2) slightly affected, where only a few bare patches are seen and the crops on the remainder are still good. In one or two instances I have re-classified the soils of the village; but as a rule I found Mr. Smith's rates so moderate, and such ample allowance made for actual deterioration as he found it to exist, or for any cause justifying a deviation from his average rates, that, though his system of classification and applying rates differs somewhat from that employed in the settlement of the Cawnpore district, I have not felt justified in interfering with the principle of his assessment, and have confined myself to applying his rates and carrying out his views, as expressed in his village notes, to their legitimate conclusion as warranted by existing circumstances. At the same time I must remark that the system of applying one broad rate to the whole of a village must result in hardship in individual instances, even if it be conceded that a fair average rate for the whole village is obtained, which I doubt; it is impossible to apply the same rate to compact *hárs* of high good land and to scattered fields in *úsar* or low-lying land in drainage courses.

13. I inspected all the villages (16) on which Mr. Smith reported as affected by *reh*; those injured by inundation alone, unconnected with *reh*, I considered beyond the object for which I was deputed, though it has frequently happened that constant flooding has, probably salts washed down from high *úsar* in the neighbourhood, sterilized much land, at least temporarily (e. g., Ginoli and Jan Inayatpur), and on such villages I report. I have, in addition, inspected nine others of which the maps were ready and which lay in the *reh*-affected tract.

14. In the following villages I propose a reduction of revenue for reasons given under the head of each mahál, V., Abstract:—

Pargana Akhrabad.

Ladhwa.
Subaoli.
Kanakpur.
Gudmai.
Na Alia.
Silpura.
Mandanpur.
Amosi.

Pargana Sikandra Rao.

Girdharpur.
Ginoli Kishanpur.
Bahadurpur.
Manora.
Jahangirabad.
Deori (4 maháls).
Jau.

15. I would respectfully submit that orders, either allowing the reduction I propose or otherwise, be passed without delay. Mr. Smith inspected at the end of 1876 and recommended reduction, but no action has as yet been taken, and there is no doubt this state of suspense is injurious to Government and proprietor. At the same time I would suggest that the present settlement with the estates in which I recommend a reduction be annulled and a fresh engagement taken for five years; by such a

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provision the interests of both Government and proprietor will be protected. Should remedial action be taken and prove efficacious, much, if not all, of the land now thrown out of cultivation, it may be hoped, will again come under the plough. In a shorter period than five years the zemindar would be hardly able to recoup himself the expense of bringing the land again under cultivation, and would not, therefore, be encouraged to do so. At the same time, unless some remedy is carried into effect, the injury already so widespread must increase. The condition of the village can be carefully watched by means of the agency of supervising kanúngos, and a fair basis for a fresh assessment at the end of the term proposed be obtained.

16. In the following villages inspected by me no present action is called for :—

Kiratpur.	Rudian.
Bhinoli.	Khera Sultanpur.
Gopi.	Na Gobind.
Pempur.	Rizapur.
Na Kamlu.	Sherpur.
Na Mirza.	Basei.
Chandpur.	Baramai.

In the following, the chief remedy called for is an efficient system of drainage :—

Ginoli—through Bahadurpur to river Rind.

Jan—through Bakain to Hosain, with a syphon under the rájbaha.

17. In conclusion, I would submit that any relief given to the proprietors should be accompanied by prompt and thorough relief extended to the cultivators. This would be done under section 23, Act XVIII. ; but as the effect of action under that section would probably be only legal for one year, in my opinion the better plan would be to invest some good deputy collector (such as Bihari Lal now at Mainpuri) with power to readjust rents under section 72, Act XIX. By this course every cultivator would be able to obtain a hearing at but little expense, and the rents of non-occupancy tenants could be arranged on some definite terms. At present, in many of the estates the occupancy tenants have broken down and their place has been taken by new cultivators. In some instances these can only get the land at the old high rates, or even higher; the zamindar says, "how else can I pay my revenue?" But if it was generally understood that low renting were to be the rule, I think proprietor and cultivator would accept the position. That some such understanding would be beneficial and is much wanted is, I think, shown by the fact that cultivators have had so little recourse to suits for abatement; they seem in doubt as to where they should apply, or perhaps have applied, and failed for want of some recognised principle on which the relief could be granted.

Statement showing depth to water in wells measured by me during my investigations into reh-affected villages in tahsil Sikavāra Rao, zila Aligarh.

1	2	3	1	2	3
Name of village.	Depth to water.	Remarks.	Name of village.	Depth to water.	Remarks
	Feet.			Feet.	
Amosi ...	7	The factory well ...	Na Alia ...	10½	
Ginoli Kishanpur,	10	...	Ladhwa. ...	...	In village site near canal.
Manora ...	9	Three wells, including the masonry well across river.	Maudanpur ...	9½	
				6	

Reh-affected villages in tahsil Sikandra Rao, zila Aligarh--(concluded).

Extract from a letter
by F. N. WRIGHT,
Esq.

1	2	3	1	2	3
Name of village.	Depth to water.	Remarks.	Name of village.	Depth to water.	Remarks.
	Feet.			Feet.	
Rizapur ...	8	...	Bhinoli ...	12	On higher ground.
...	13	High ground.	...	10	Nearer river.
Sherpur ...	10	Ordinary field level.	Kanakpur ...	8	In manjha, north of river.
...	10	In village site.	...	7	Village site.
Baramai ...	9	Na Kanakpur.	Suhaoli ...	11	On a khera.
...	12	Na Chamoli.	...		
...	10	Na Bijan.	Between Jau and		
...	9	In usar south of ditto.	Háthras road sta-		
...	6	Close to canal.	tion.		
...	10	In large grove.	Na Rata ...	11 and 12	
Na Gobind ...	14	Rather high ground.	Kánch káan ...	11	
Girdharpur ...	11	Near site.	Salempur ...	14 to 22	Deepening south-
...	13	In outlands north-west.	...		wards.
Gudnai ...	10	...	Bholi ...	20 to 30	Ditto.
Basei ...	9	Between canal and	Pakra ...	21 to 27	
...	10 and 11	rájba	Bahanpur ...	24 to 30	
...	11 and 12	North of site.	Kelu ...	36	
Bahadarpur ...	10	Village site in úsar.	Bohra ...	30	
...	6		All round Háthras	50 to 36	
...			road station.		

Extract from a letter from F. N. WRIGHT, ESQ., Settlement Officer of Cawnpore, to the Director of Agriculture and Commerce, N.-W. P. and Oudh, No. 110, dated the 23rd March, 1878.

THERE is not the least doubt of the great rise in water-level in the vicinity of the canal. Not only is the normal level according to my experience about 20 to 25 feet in such tract, whilst here it is 6 to 12 feet, but the old bullock-runs show it to have been much further below the surface formerly, and the levels I took as I receded from the canal lead to the same conclusion.

As I had left the neighbourhood of the Grand Trunk Road before your letter reached me, I was unable to note the effect of the canal in alternate weeks. I saw at Jau water oozing up through the soil where the canal was running full and above the level of the surrounding country.

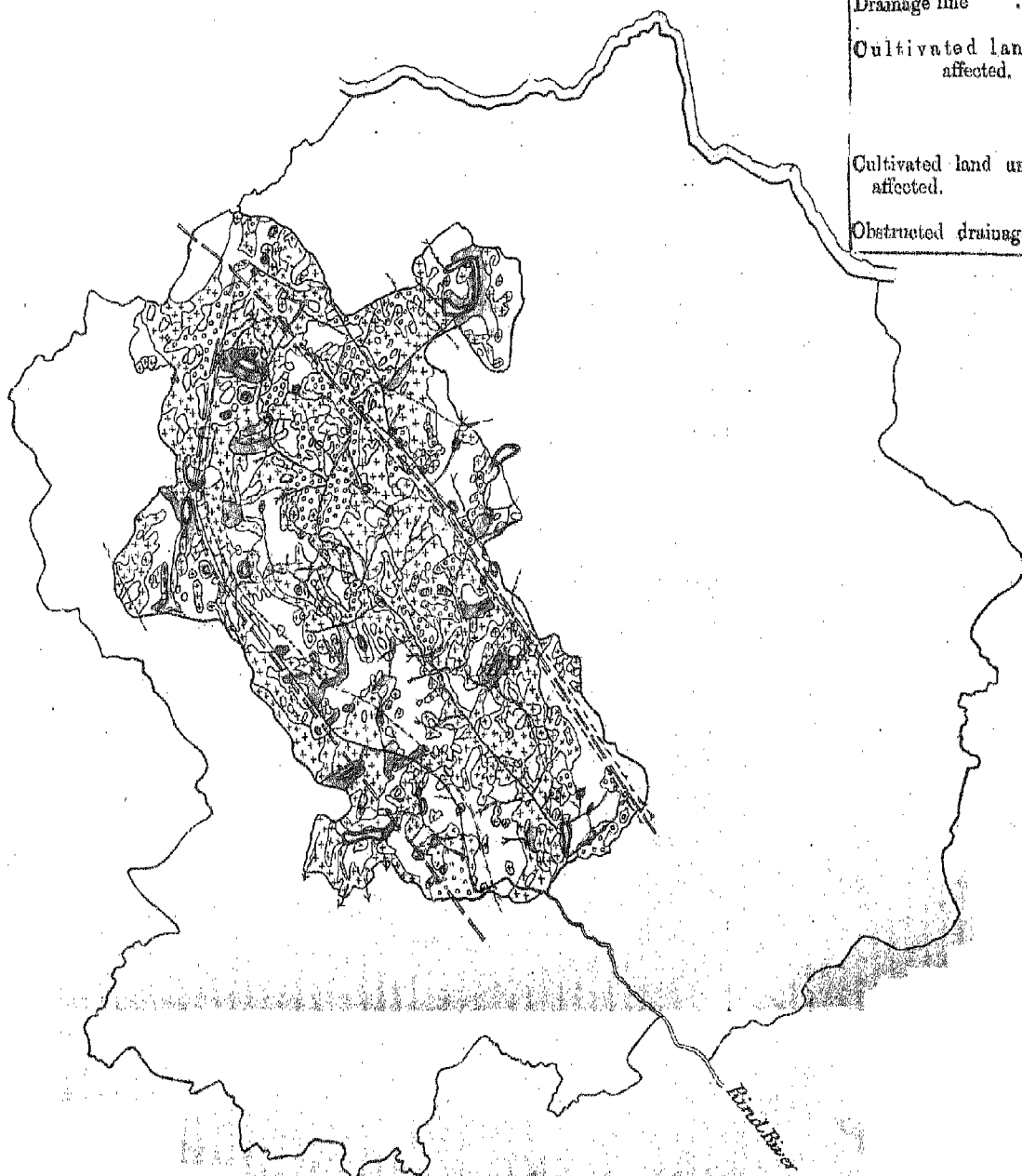
TAHSIL SIKANDRA, ZILA ALIGARH.

SHOWING

REH-AFFECTED TRACTS.

REFERENCES

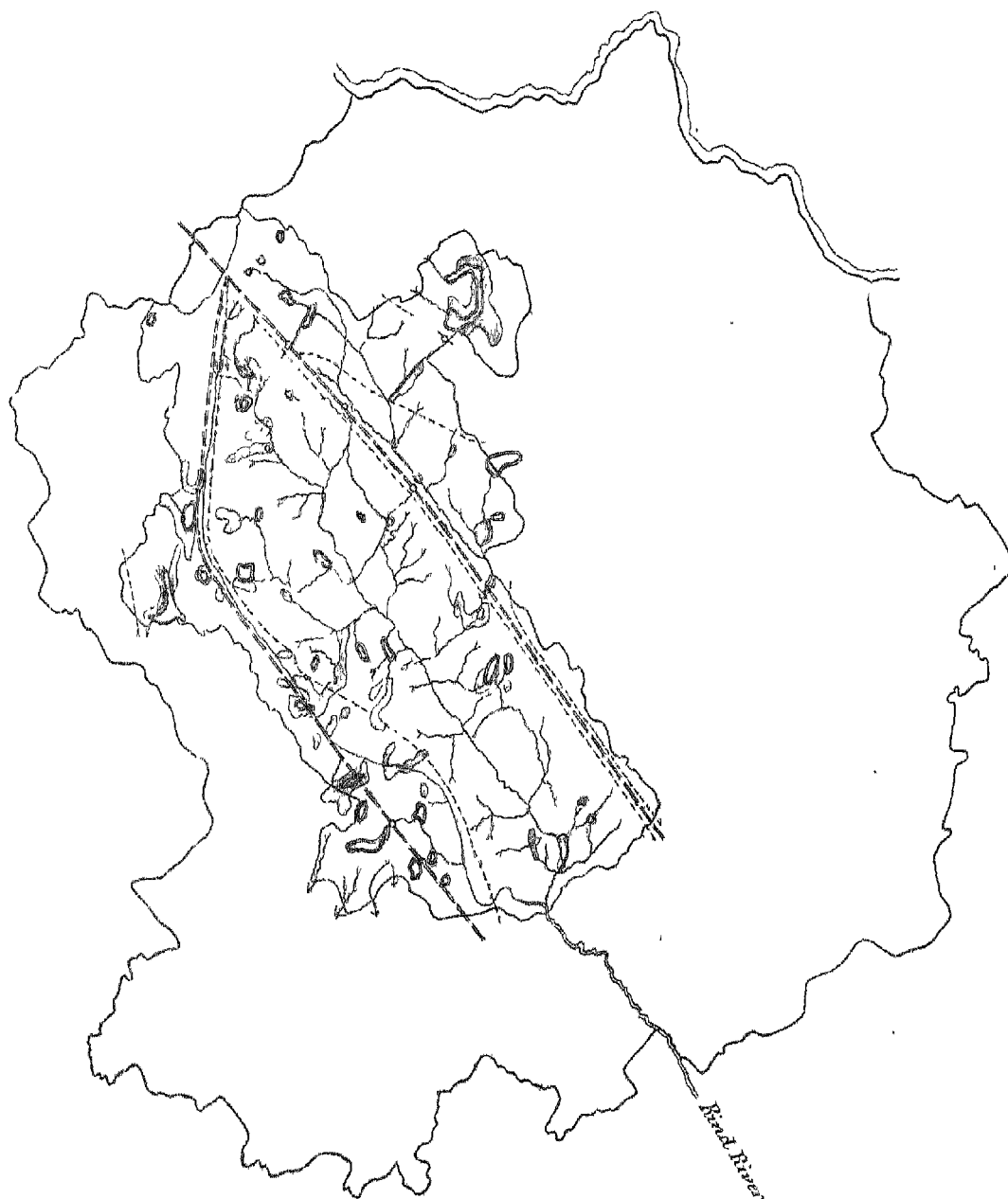
Rajbaha	...	---
Canal	...	----
Usar land	...	----
Usar land partly affected by Reh.	...	+++ ++ ++
Usar land much affected.	...	ooo oo oo
Tarai	...	----
Gandar grass	...	----
Pond	...	o
River	...	---
Drainage line	...	---
Cultivated land affected.	...	+++ ++ ++
Cultivated land unaffected.	...	---
Obstructed drainage.	...	o



SCALE—THREE MILES TO AN INCH.

DRAINAGE MAP.
OF
TAHSIL SIKANDRA, ZILA ALIGARH.

REFERENCES.	
Rajbaha	---
Canal	---
Tarai	...
Gandar grass	...
Pond	...
Drainage lines	...
Rivers	...
Obstructed Drainage	o



SCALE—THREE MILES TO AN INCH.



DRAINAGE MAP

67

PARGANAS SHIMBAJPUR AND BILAU, JAJMAU KACHHAR,

ZILA CAWNPORE,

SHOWING DISTRIBUTION OF USAR AND REH.

SCALE - THREE MILES TO ONE INCH

Yellow indicates usar.

Red " Efflorescent reh.

Blue indicates water.

Brown " low lying alluvial deposit below the cliff.

No. 12 - The dotted line is the watershed.

A to B is the drainage basin of the river Nila, and is a shallow hollow full of ponds and lakes which are surrounded by red flaps.

From B. to C. the river runs through high rocky banks, and there is no water except in patches close to the edge.

In C. to D. reh is abundant and increases rapidly when irrigated. There is little room to doubt that reh has been carried by the river Nila from B. to C. in a distance of ten to fifteen miles.